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DESIGN AND THEORY OF OPERATION—SAFETY-IGNITION DEVICE FOR APPLICATIONS TECHNOLOGY SATELLITE ROCKET MOTOR

November 1968

U.S. ARMY MATERIEL COMMAND
HARRY DIAMOND LABORATORIES
WASHINGTON, D.C. 20438

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by

Edward N. Freeman

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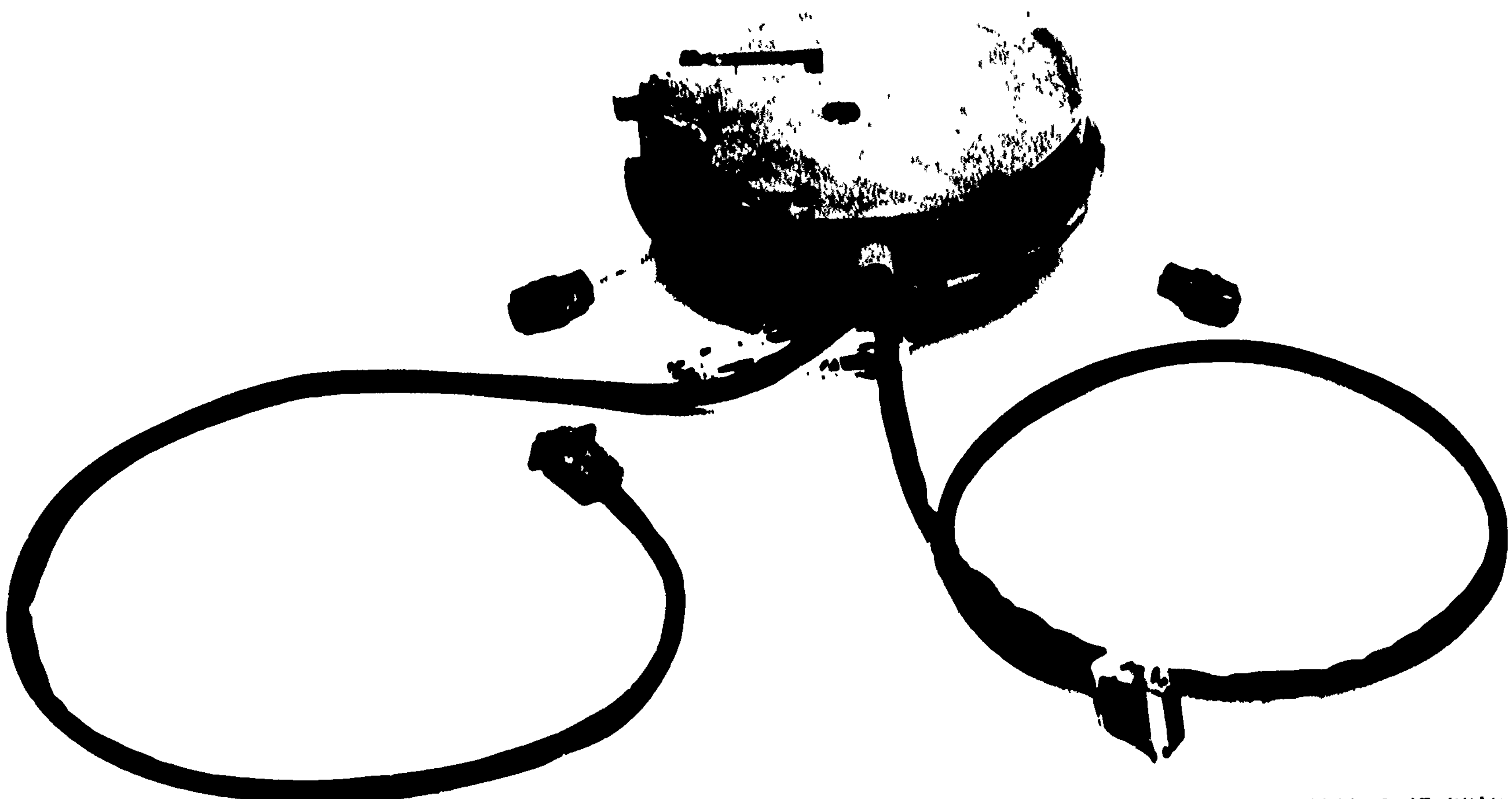

NASA C-67-9010

Frontispiece.

ABSTRACT

This report describes and illustrates the design and operation of a safety-ignition device (SID) that was developed for use with a 750-lb solid-propellant apogee rocket motor (designed by the Jet Propulsion Labs). This device, used in combination with the Applications Technology Satellite for NASA, is primarily intended to prevent ignition of the rocket motor during ground handling and prelaunch operations, and in orbital flight provide reliable ignition of the apogee rocket motor with a high degree of safety and operational reliability.

Based on an extensive test and evaluation program conducted during this development, the design recommended herein is considered suitable for the desired application.

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Cont'd)

1. INTRODUCTION

Research and development work was initiated[1] by HDL in December 1964 on a safety ignition device (SID) for the Applications Technology Satellite (ATS) apogee rocket motor. This device was required to prevent premature ignition of the JPL apogee rocket motor during ground handling and prelaunch operations while in the safe position, and permit reliable ignition of the apogee motor in the armed position. The design specifications further required that the SID perform with a high degree of safety and reliability and that it be compatible with the:

(a) Existing configuration of the rocket motor (illustrated in sect 2.3);

(b) Weight and CG characteristics dictated by propulsion and payload of the motor (illustrated in sect 2.3); and

(c) Environmental conditions experienced by the rocket during prelaunch and flight.[2]

In addition to the above general requirements, the SID was required to produce an output-pressure signature at a temperature conducive to reliable ignition of the pyrotechnic charge in the rocket without causing excessive motor chamber pressure, and at the same time be compatible with the squib-driver electric output. The SID was placed in the armed configuration by an electrical signal from a blockhouse console.

Two SID designs—designated A and B—were developed during this program. This report describes and illustrates the design and operation of those two devices. A detailed test-data report containing the performance of Design B (shown in frontispiece) was submitted by HDL to NASA in June 1967. That report[3] is concerned specifically with an evaluation program that was directed toward establishing the design and determining the overall capabilities of the SID with respect to the desired application.

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[1] Upon authorization by National Aeronautics and Space Agency, Goddard Space Flight Center, request number S-70031-G, dtd 3 Dec 1964.

[2] "Environmental Qualification and Acceptance Test Specification—Spacecraft Testing," prepared by Goddard Space Flight Center, No. S2-0101.

[3] "Report On Evaluation Program for Safety Ignition Device for Applications Technology Satellite Rocket Motor," compiled by Martin Nelson, June 1967.

2. GENERAL DESCRIPTION OF SID DESIGNS

2.1 Design A

Design A, which established the basic configuration, employs an out-of-line mechanism, an associated drive system, and a switching system.

2.1.1 Out-of-Line Mechanism

The out-of-line mechanism shown in figure 1 consists of three parts—a lower body, an upper body, and a core inclosure, as shown in figures 2, 3, and 4, respectively.[1]

The lower body contains the O-ring seal between the upper and lower bodies and the lower-core shaft bearing. Also incorporated in the lower body is a curved slot with which a pin in the base of the core mates, thus limiting core rotation. Externally, the lower body provides a seat for the closure nut (item 4, fig. 5), which holds the unit in the rocket-motor casing, the closure O-ring seal groove, and the mating threaded section to retain the Alclo basket shown in item 1 of figure 5.

The upper body contains two squib cavities with the necessary porting to conduct the squib combustion products to the passages in the core. An upper-core shaft bearing and its O-ring seal are contained in the upper body.

The core inclosure contains two pairs of ports, either pair of which may be aligned with the ports in the upper body. One pair of these ports (sect B-B, fig. 1) conducts the squib-combustion products into an expansion chamber within the core itself. The other pair of these ports (sect A-A, fig.1), displaced 60 deg from the first pair, merges into a common port on the axis of rotation and conducts the squib combustion products through the lower body to the Alclo basket (fig. 5), which is the next element in the pyrotechnic train if armed.

2.1.2 Drive System

The associated drive system (fig. 1) employs a pair of linear solenoids attached to opposite ends of a rod with a gear-toothed rack along one side. This pair of solenoids drives a pinion

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[1] Illustrations appear on pp. 17 - 39.

gear on the core-shaft extension. One of these solenoids accomplishes the safing function; the other accomplishes the arming function. A third and smaller solenoid engages a latching device on the side of the drive rod opposite the toothed rack, locking the rack in either the safe or armed position.

2.1.3 Switching System

The switching system illustrated in figure 6 employs four micro switches that are actuated by cam surfaces machined on the drive rod. These switches limit the switching functions for the solenoids and provide remote indication of the safe or armed position of the SID.

2.2 Design B

Initially, Design B was intended to provide only an alternate drive system for the out-of-line mechanism employed in Design A. As Design B evolved, however, additional switching requirements were imposed upon the system, limiting the quantity of micro switches required in view of the limited space in Design A. Design B utilizes a reversible d-c motor and a worm-and-wheel drive system, which is inherently compatible with printed-wiring-type switching devices. Consequently, a printed-wiring switching system was developed to accommodate the required switching functions.

During this period of development, Design A had progressed to the prototype hardware phase and units were being field tested. The results of these tests indicated that isolation of the output port from the squib ports during squib firings in the safe position was not commensurate with the desired application. An investigation of this problem resulted in full development of Design B.

The basic igniter unit for this design is shown in figure 7. This unit consists of an upper body and a lower body that inclose a rotatable core.

2.2.1 Upper Body

The upper body is shown in figure 8. It contains a central stepped cylindrical cavity—with which the core (fig. 9) mates—and two diametrically opposed ports. In cross section, the two ports are threaded at the outer end to accept the squibs and extend downward at a 45-deg angle from the threaded portion until they intersect the central cylindrical cavity.

2.2.2 Lower Body

Figure 10 illustrates the lower body, which is a stepped cylindrical base that mates with the upper body and closes the bottom of the core cavity. In cross section, the lower body has two ports in its surface that extend downward toward the center at a 45-deg angle and intersect a larger vertical port that extends to the lower surface. This porting arrangement is a Y-configuration.

2.2.3 Core

The core, illustrated in figure 9, is a solid cylinder that has been cut away on parallel sides, leaving a thin, full cylinder at the bottom and a rectangular parallelepiped section with curved ends for the remaining height. In cross section, the core has a port at each end which extends at a 45-deg angle from the curved surface of the parallelepiped section to the base of the thin cylindrical base.

2.3 Theory of Operation — Design B

When the three parts of the basic igniter unit are assembled, the core is capable of a 60-deg rotation. In the extreme clockwise position, the assembly is in the safe position, and the ports in the core are displaced 60 deg from the ports in the upper and lower bodies, effectively sealing the ports in the lower body and placing the expansion chambers adjacent to the ports in the upper body.

In the event of an accidental squib firing in this position, the combustion products will impinge upon the upper curved surface of the core, forcing its base tightly against the lower body and sealing off the ports in the lower body. The combustion products are contained within the expansion chamber.

Neither squib can ignite the other, because the two expansion chambers are not interconnected. However, if both squibs are accidentally fired simultaneously, combustion products would impinge upon the curved upper surfaces of both sides of the core, thus providing a greater sealing force than that from a single squib.

In the extreme counterclockwise position, the unit is in the armed position and the ports in the core are aligned with the ports in both the upper and lower bodies. The expansion chambers are isolated from the ports in the upper body. Upon initiation of the squibs in this position, the combustion products pass through the two squib ports, combine in the central port, and then pass into the Alclo basket. It should be noted at this point that a single squib is capable of igniting

the Alclo basket and the second squib provides redundancy.

The device is actuated by a subminiature d-c motor, magnetic-brake reduction-gear unit (fig. 11) which, through the worm-and-wheel arrangement, rotates the core.

Incorporated in the drive system is the manual safing capability. Safing is accomplished by removing a locking pin and rotating the manual safing lever clockwise approximately 71 deg. In its first 11 deg of travel, the lever pivots the motor, disengaging the worm from the worm wheel. At this point, the lever engages a pin mounted on the lower surface of the worm wheel and then rotates the worm wheel 60 deg, placing the device in the safe position. Returning the lever to its initial position reengages the worm with the worm wheel, locking the device in the safe position. The lever cannot arm the device. Manual arming has been intentionally omitted from the design.

Mounted above the drive system is the printed-wiring-type rotary switch. The rotating-switch element is attached to the top of the worm wheel, and the stationary element is supported by four posts that are screwed into the lower body. Electrical connection between these two elements is accomplished with spring contacts. This switch combines the eight switching functions required, as described below (fig. 12):

Switch No. 1 connects one end of squib No. 1 to the "squib No. 1 fire" lead in the armed position and to ground in the safe position.

Switch No. 2 connects the other end of squib No. 1 to "squib No. 1 return" in the armed position and to ground in the safe position.

Switch No. 3 performs the motor cutout, or limit functions, in the armed or safe mode; also, it performs the indicator functions for these two positions.

Switch No. 4 parallels the motor limit switch functions of switch No. 3 and provides redundant safe or armed indication.

Switch No. 5 short circuits both ends of squib No. 1 to ground in the safe position and removes this short in the armed position.

Switch No. 6 short circuits both ends of squib No. 2 to ground in the safe position and removes this short in the armed position.

Switch No. 7 connects one end of squib No. 2 to the "squib No. 2 return" in the armed position and to ground in the safe position.

Switch No. 8 connects the other end of squib No. 2 to "squib No. 2 return" in the armed position and to ground in the safe position.

The end of the cable attached along the periphery of the stator terminates in two connectors, which connect to the spacecraft internal wiring harness—one 15-pin Cannon DAM-15P-SNB-1 that carries the control and indicating circuits, and one 9-pin Cannon DEM-9B-SNB-1 that carries the squib-driver circuits. The control and indicating circuits are connected through the missile wiring harness and umbilical cord to the control panel (fig. 13) located in the launch console of the blockhouse.

Figures 14 and 15 illustrate a checkout box that is used to indicate the safe or armed positions of the device at any time before installation of the rocket motor in the spacecraft. This checkout box is a passive indicating instrument and has no control functions.

An exploded view of the complete unit is shown in figure 5; the assembled unit is diagrammed in figures 16 and 17. Figure 18 shows the assembled apogee rocket motor.

3. HISTORY OF SID DEVELOPMENT

3.1 Squib Selection

In the initial phases of this program, it was assumed that the same squib developed for the SYNCOM program would be applicable in the ATS program and would be provided by NASA. However, the squibs were not available and HDL was directed by NASA to conduct a squib evaluation program,* in which the following squibs were used:

Navy-type WOX-1A

Special Devices 101575 (SDI-Gemini)

Special Devices I

Hercules

Hi-Shear PC-37

Of the igniter squibs evaluated, the PC-37 was considered the most applicable for the SID application on the basis of its capability to (1) meet the space requirements of the apogee rocket motor; (2) withstand such tests as the pressure output, flame temperature, gap, safety and propagation, and no-fire current; and (3) withstand

* Reported by Nelson, June 1967, op. cit.

environmental testing including vibration, acceleration, and thermal vacuum. The output characteristics of this igniter squib are listed in figure 19.

3.2 Materials Used

Wherever possible, nonmagnetic materials were incorporated in the final design. The material for individual piece parts include nonmagnetic corrosion resisting steel, titanium alloy, fiberglass, teflon, and various aluminum alloys. The basic igniter, core, upper and lower bodies were constructed with AISI 303 corrosion-resisting steel by Glide-line Corp (Waynesboro, Pennsylvania). The posts and screws used to fasten these parts together were fabricated by HDL, using titanium alloy, 6AL-4V-AMS-4928. The various other piece parts were made of aluminum alloys and manufactured by the Blade Tool and Die Company (Washington, D. C.). Additional specifications and data on specific piece parts are given in HDL Engineering Parts List and Drawing numbers 11008117 and F11008777, respectively.

3.3 Physical Properties

Total weight of the assembied SID—loaded with the squibs and ready for flight—is approximately 5 lb. Figure 20 shows its center of gravity and moment of inertia.

3.4 SID Assembly

The mechanical assembly and electrical wiring is covered in the complete engineering drawing package, Parts List No. 11008777 and the top assembly drawing F11008777. Quality control and inspection is described in HDL drawings C11009008 and C11009009, respectively. This includes Contact-Position check of the stator board, using HDL contact-assembly fixture F1108674 and contact-preload inspection in which a GO continuity gage and a NO-GO continuity gage were used. A low-pressure (15 psig) test was also used on the assembled SID's to determine if the O-rings were installed and functioning properly. The setup for this pressure test is outlined in HDL drawing C1109012. See appendix A for assembly details.

3.5 Problem Areas

During the development phase, it was determined that the operating pressure of the rocket motor was higher than first suspected. Thus, the pressure within the SID igniter chamber increased. To compensate for the increased pressure, the upper- and lower-body retaining screws were increased in number and size. In the early design B development phase, six (6-32) UNC titanium screws were used to fasten

the upper and lower bodies together. In the final design B, 10 (10-32) UNF titanium screws were used. Prototype units of this design were checked hydrostatically to 5000 psig, then disassembled and inspected. Test results confirmed that the assembled design B is capable of withstanding 5000 psig without any degradation to the individual parts.

To satisfy the drive-source requirements for high torque, low speed, direct cutoff with little or no cost, reversible direction and miniature size, a magnetic brake, reduction gear, a subminiature d-c electric motor was incorporated. This motor (PART No. 43A965), manufactured by Globe Industries, Inc (Dayton, Ohio), incorporates an electric magnetic brake, wired in series with the motor armature windings.

Problems were encountered with this motor in that it hadsticking brakes and an erratic operating current. It was determined that the air gap between the disc and coil housing changed after a period of operation. All motors were returned to the manufacturer and reshimmed to correct the air gap. Also, the motors were recalibrated for a correct running current and brake-dropout current. After this, each motor was operated 100 times and then recalibrated to compensate for wear. Although the manufacturer rebuilt and rechecked each motor to improve its reliability, a rebuilt motor failed a bench check at HDL during October 1967. After replacing the motor in the SID, the unit performed properly. Inspection with the brake-housing cover removed indicated that the air gap was between 0.002 and 0.004 in. and that the brake was dragging on the braking disc. The brake was reshimmed to the manufacturer's setting of 0.005 to 0.007 in., after which the motor operated correctly. Based on these results, HDL has concluded that periodical inspections should be made of the brake air gap and operating current to insure proper operation of the electric motor.

3.6 Inspection Procedures for Test and Orbital Flights

3.6.1 Test Flight

Between May and July 1966, eight apogee motors with SID's were fired in a dynamic rocket-motor test and one fired statically with a simulated spacecraft at Arnold Air Force Base (Tullahoma, Tenn). These SID's were modified specifically for test purposes, differing from flight hardward by inclusion of three pressure taps. Two of these taps were positioned in the lower body of the unit and the other in the upper body, as illustrated in figure 21 (HDL drawing No. 11008671). The two taps in the lower body monitored the burning pressure developed in the rocket motor. The pressure tap in the upper body monitored the squib and SID cavities, as well as the ignition and burning pressures.

All tests were considered successful, thus qualifying the SID for use with the apogee rocket motor.

3.6.2 Orbital-Flight Preparation

After the safety-ignition device was qualified for use in this application, the units were checked and prepared for shipment to the Eastern Test Range at Cape Kennedy, Florida, for orbital flight. The SID's were checked for:

(1) Electrical continuity, using the SID Electrical Checkout Procedure I, as described in appendix B.

(2) Switch-circuit contact resistance, using the SID Switch-Circuit Contact Resistance Checkout Procedure II, as described in appendix C.

(3) Low pressure at 15 psig for one-half hr, using figure C-1. No loss of pressure was indicated in this checkout.

After completing these checkout procedures with satisfactory results, the units were shipped to the test range where they were subjected to an incoming-shipment inspection and a prelaunch checkout. A copy of the procedures used by the Eastern Test Range is contained in appendix D. Following this inspection and checkout, the units were made available to JPL for installation of the igniter basket and assembly with the JPL apogee rocket motor.

4. SUMMARY

The SID design B has been determined applicable and reliable for use with the 750-lb solid-propellant apogee rocket motor, based on its performance in two orbital flights—7 December 1966 and 6 Nov 1967 aboard the ATS-B and ATS-C, respectively. The final satellite in the ATS series is scheduled to be launched in August 1969, using the SID final design.

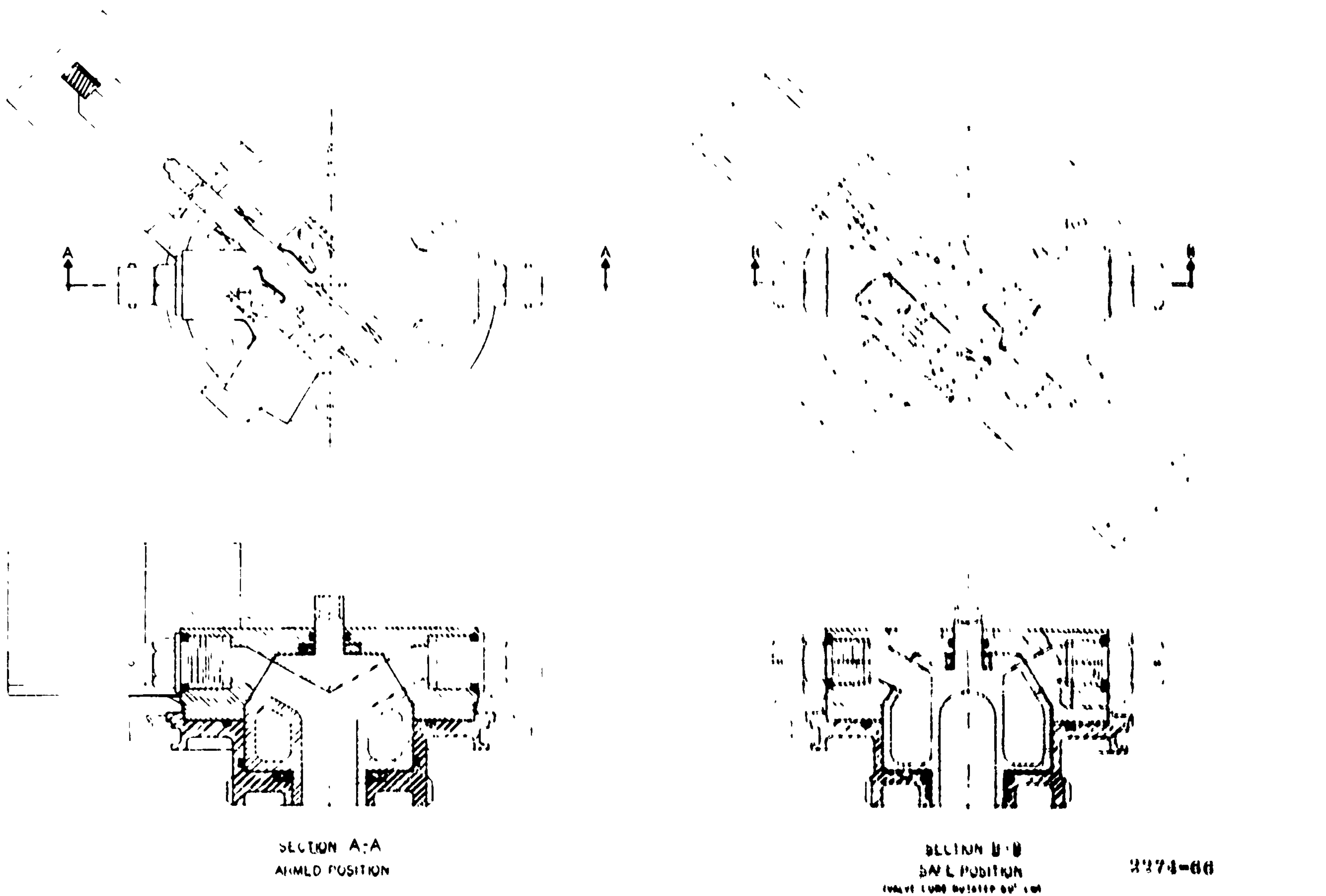

Figure 1. Diagram of SID Design A, showing out-of-line mechanism in safe and armed positions.

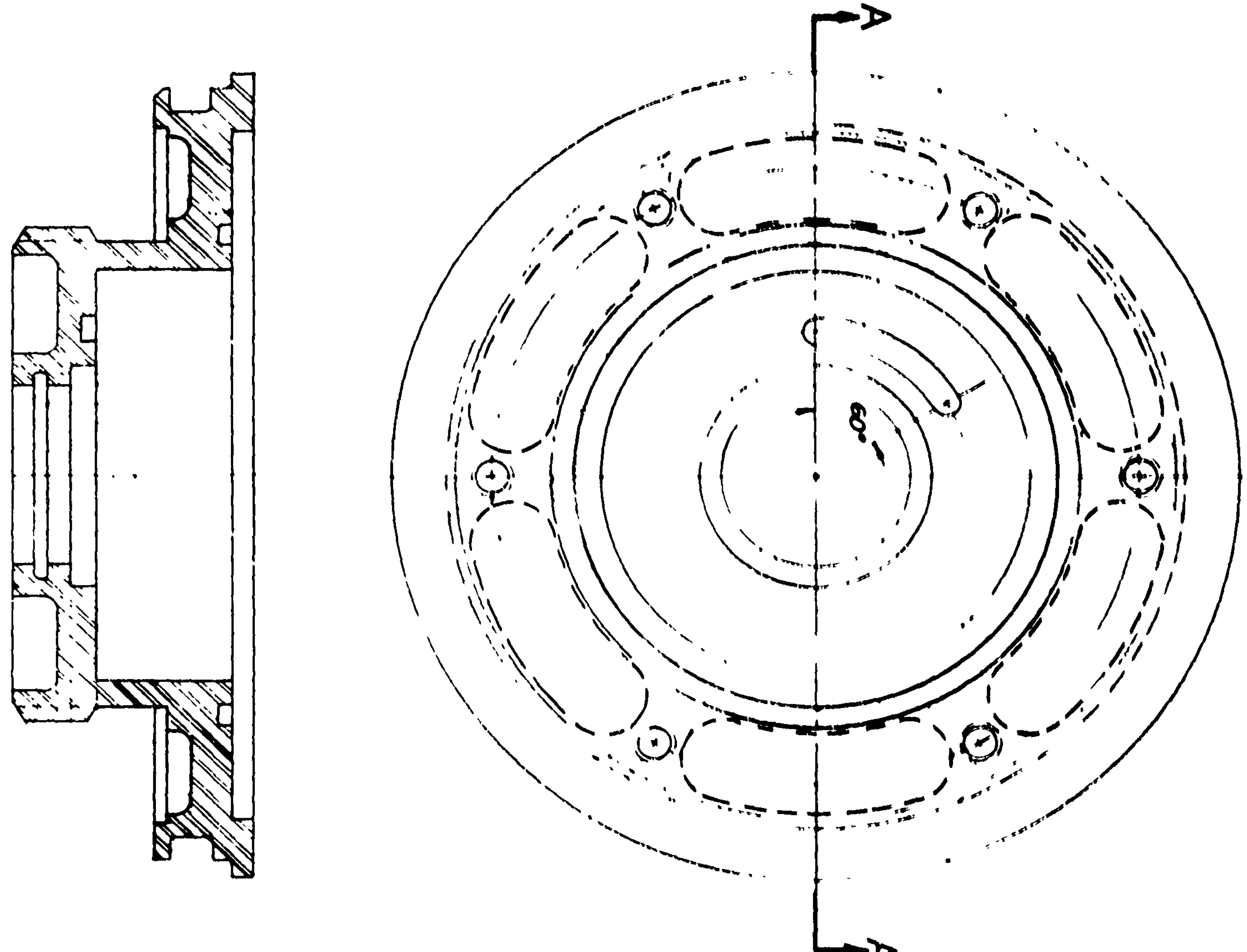

Figure 2. SID Design A, showing lower-body portion of out-of-line mechanism.

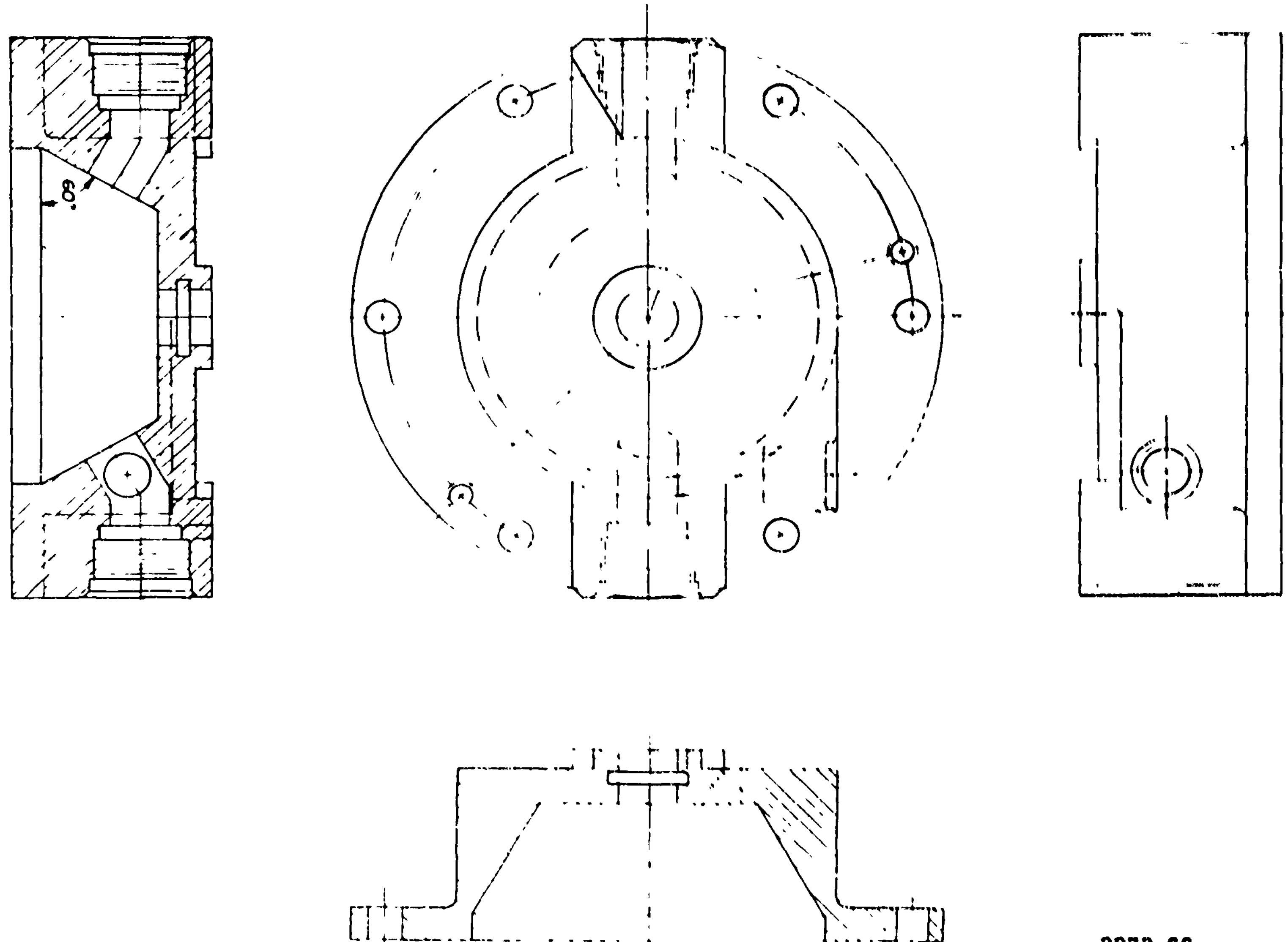

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Figure 3. SID Design A, showing upper-body portion of out-of-line mechanism.

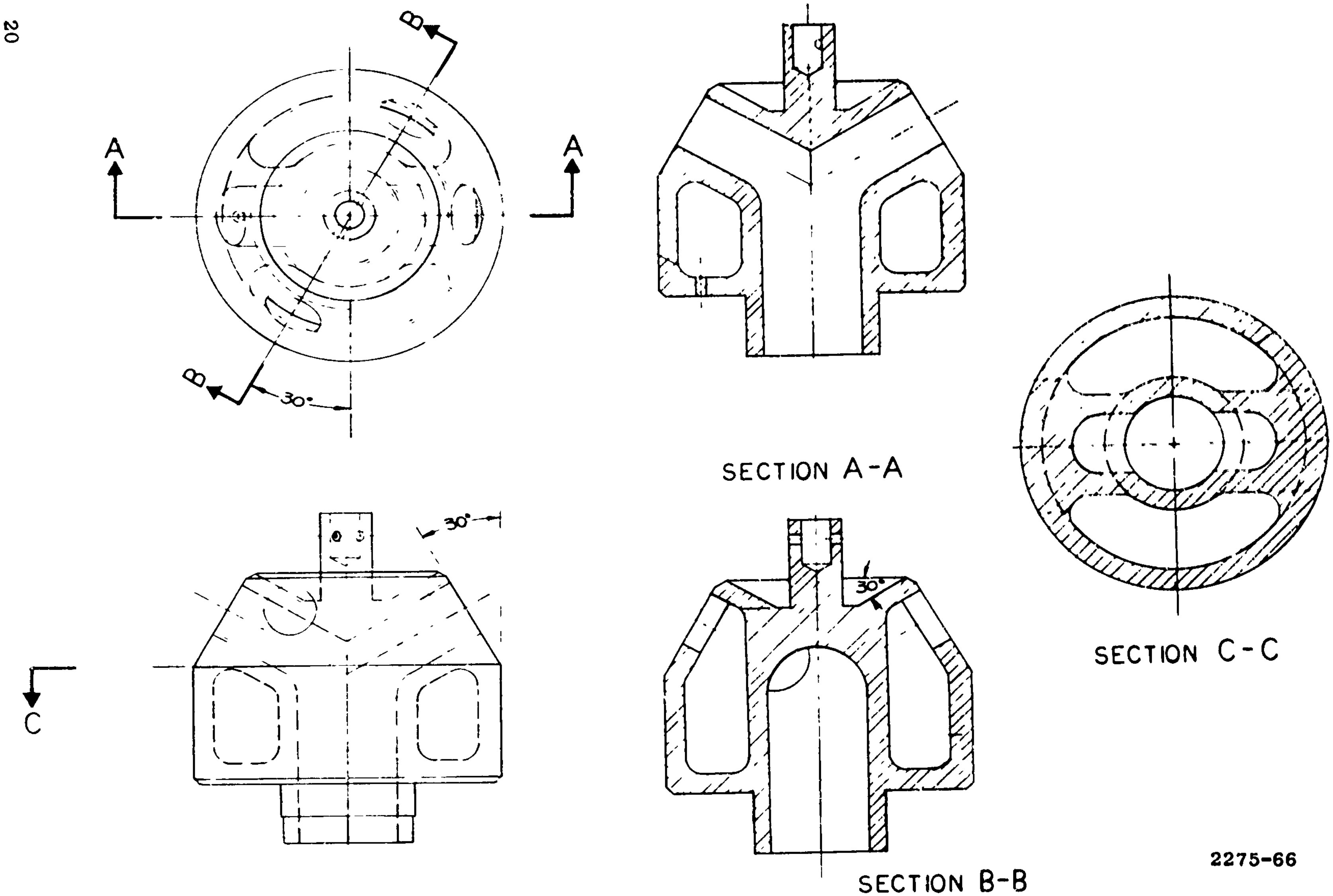

Figure 4. SID Design A, showing core inclosure in out-of-line mechanism.

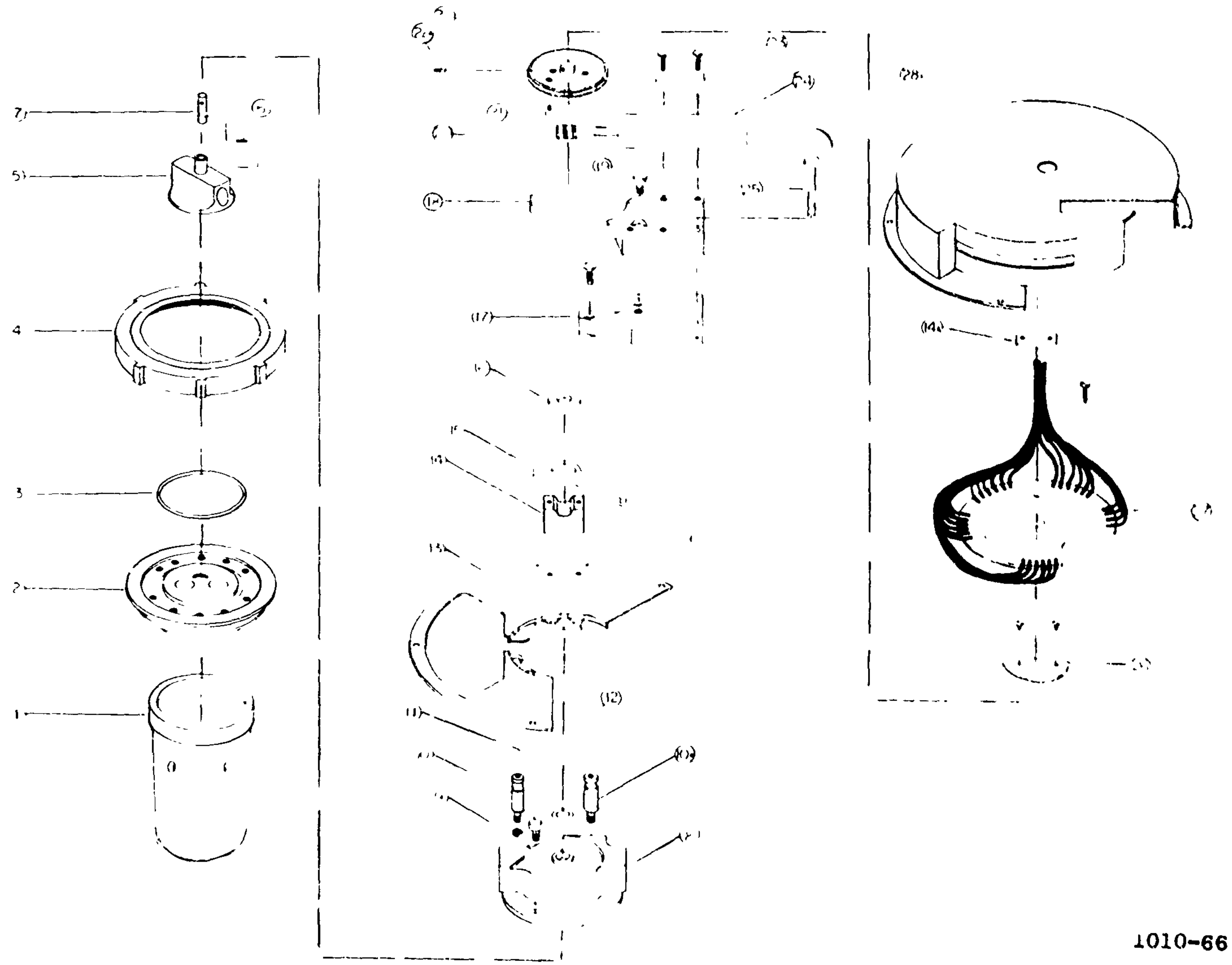

Figure 5. Exploded view of complete SID. (For Nomenclature, see next page.)

NOMENCLATURE FOR FIGURE 5

(1) Alclo basket
(2) Igniter lower body
(3) O-ring
(4) Closure nut
(5) Igniter core
(6) Roll pin
(7) Shaft
(8) Igniter upper body
(9) Lock washer
(10) Post A
(10a) Post B
(11) Socket head screw
(12) O-ring
(13) Cover base
(14) Cable clamp base
(14a) Cable clamp base
(15) Manual safing lever
(16) Spacer
(17) Base, motor mount
(18) Motor mount
(19) Shoulder screw
(20) Worm gear
(21) Worm wheel pin
(22) Worm wheel
(22a) Roll pin
(23) Cleat (one omitted for clarity)
(24) Motor assembly
(25) Manual safing release pin
(26) Printed wiring switch rotor
(27) Printed wiring switch stator—cable subassembly
(28) Cover

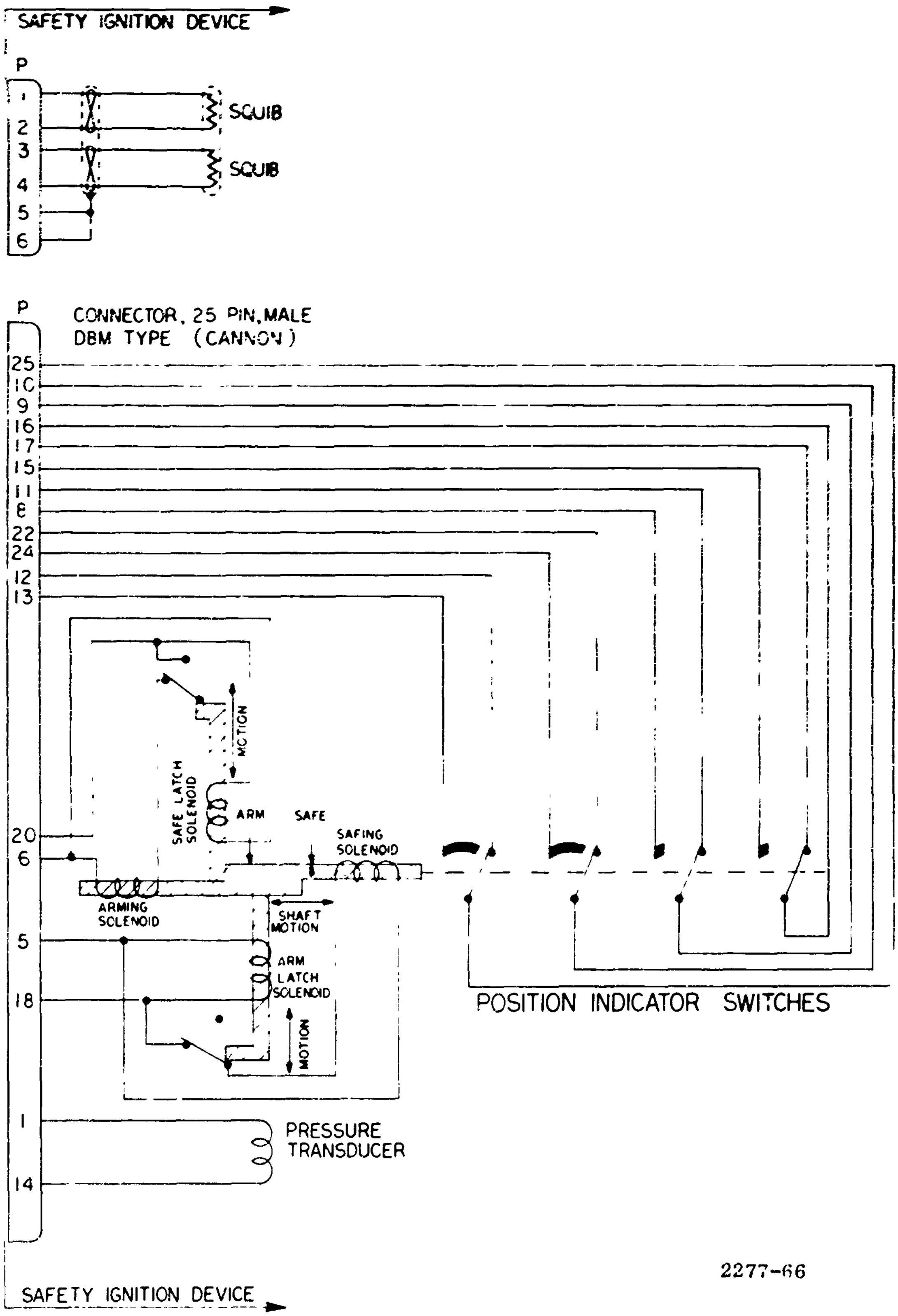

Figure 6. SID Design A switching system.

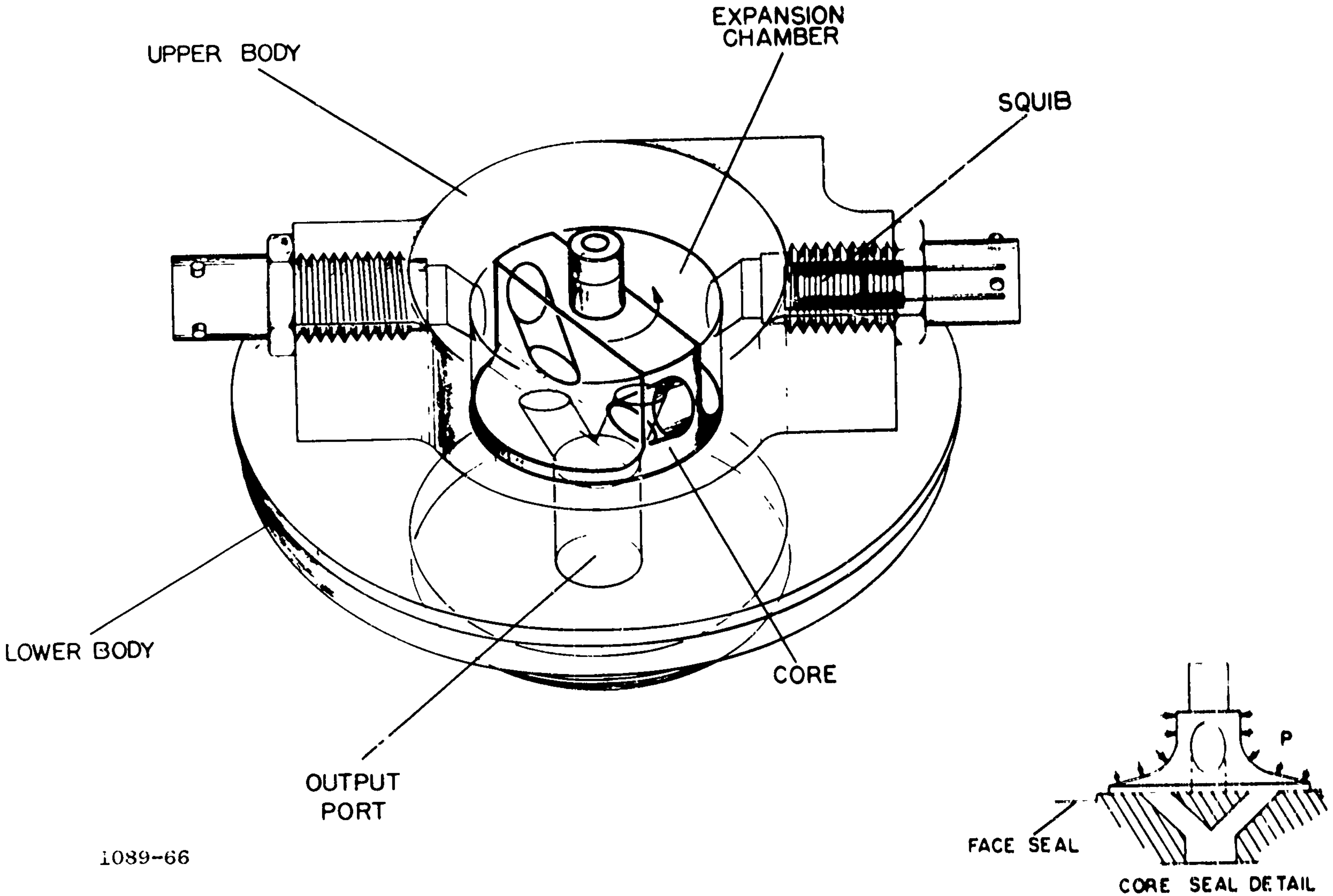

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Figure 7. Diagram showing basic igniter system of SID Design B.

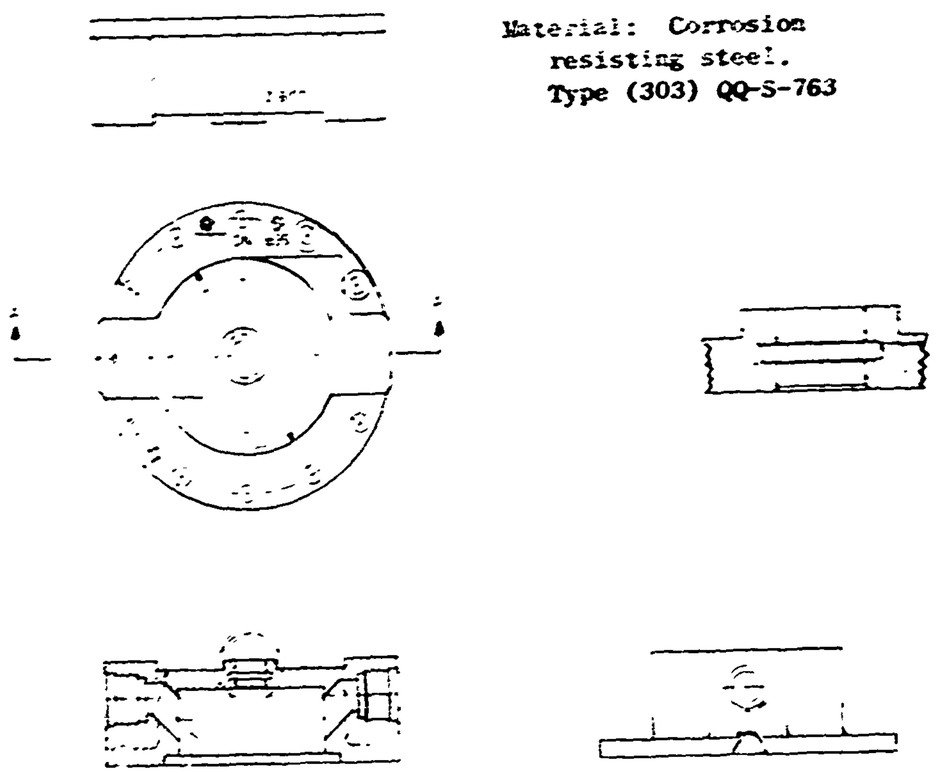

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Figure 8. Diagram of SID Design B upper body.

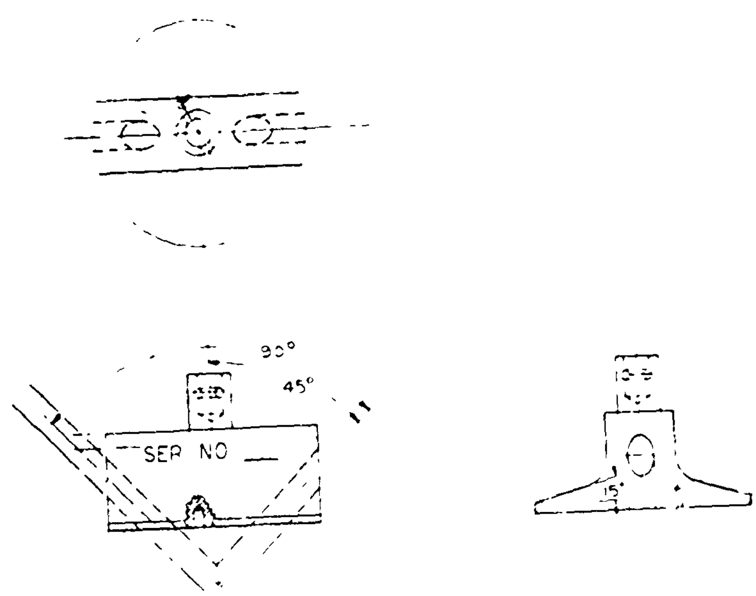

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Figure 9. Diagram of SID Design B lower body.

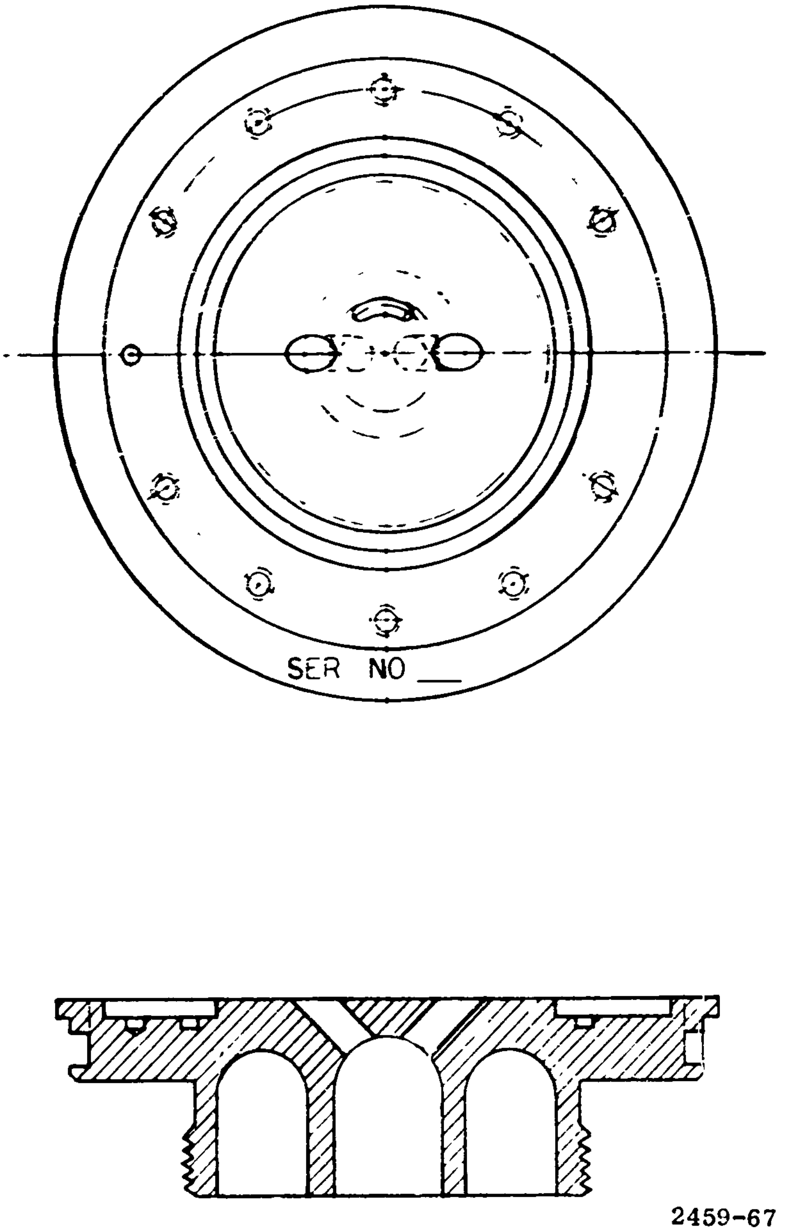

Figure 10. Diagram of SID Design B core.

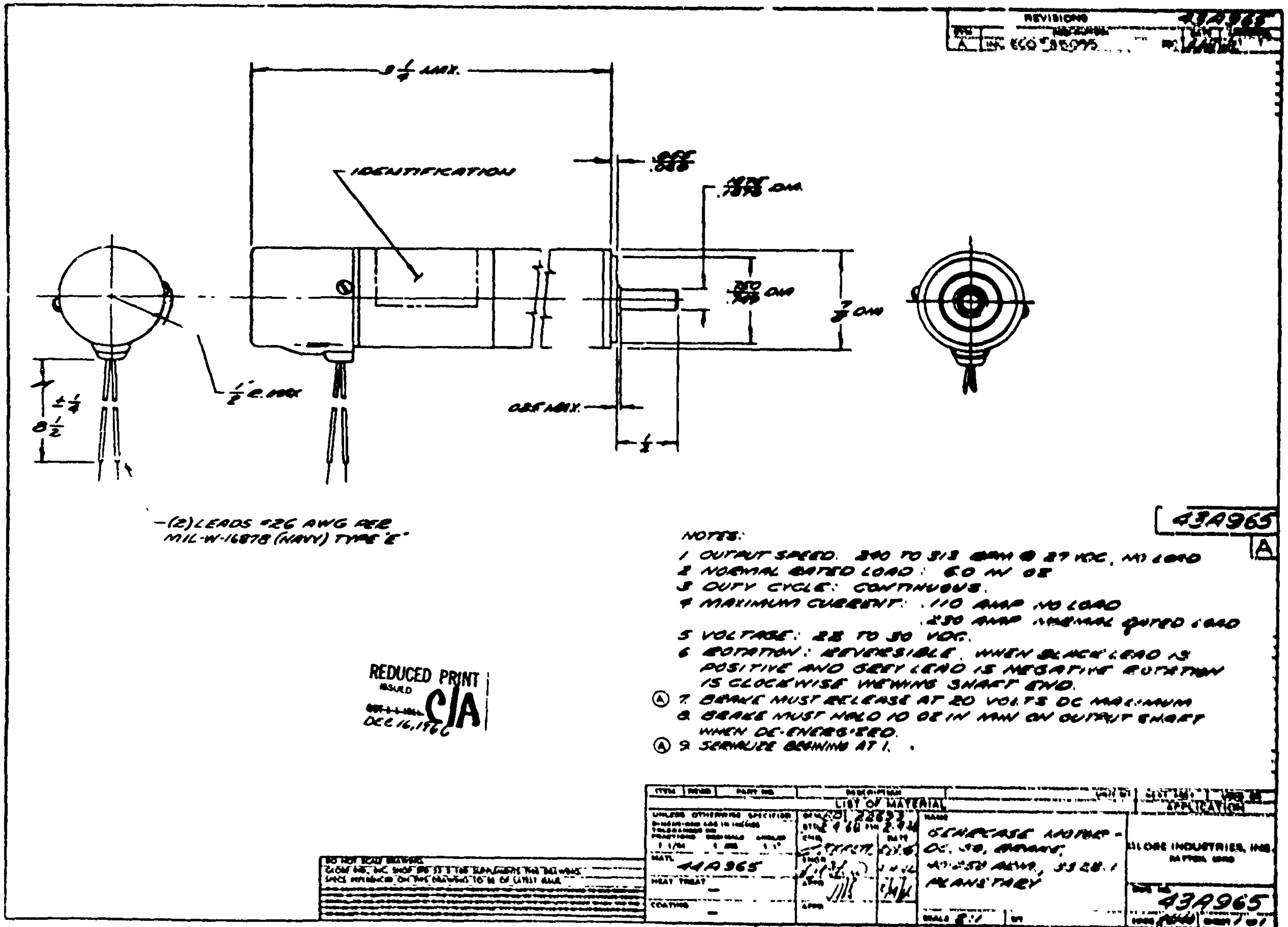

Figure 11. Diagram showing assembly details of Design B ignitor system. (Part I)

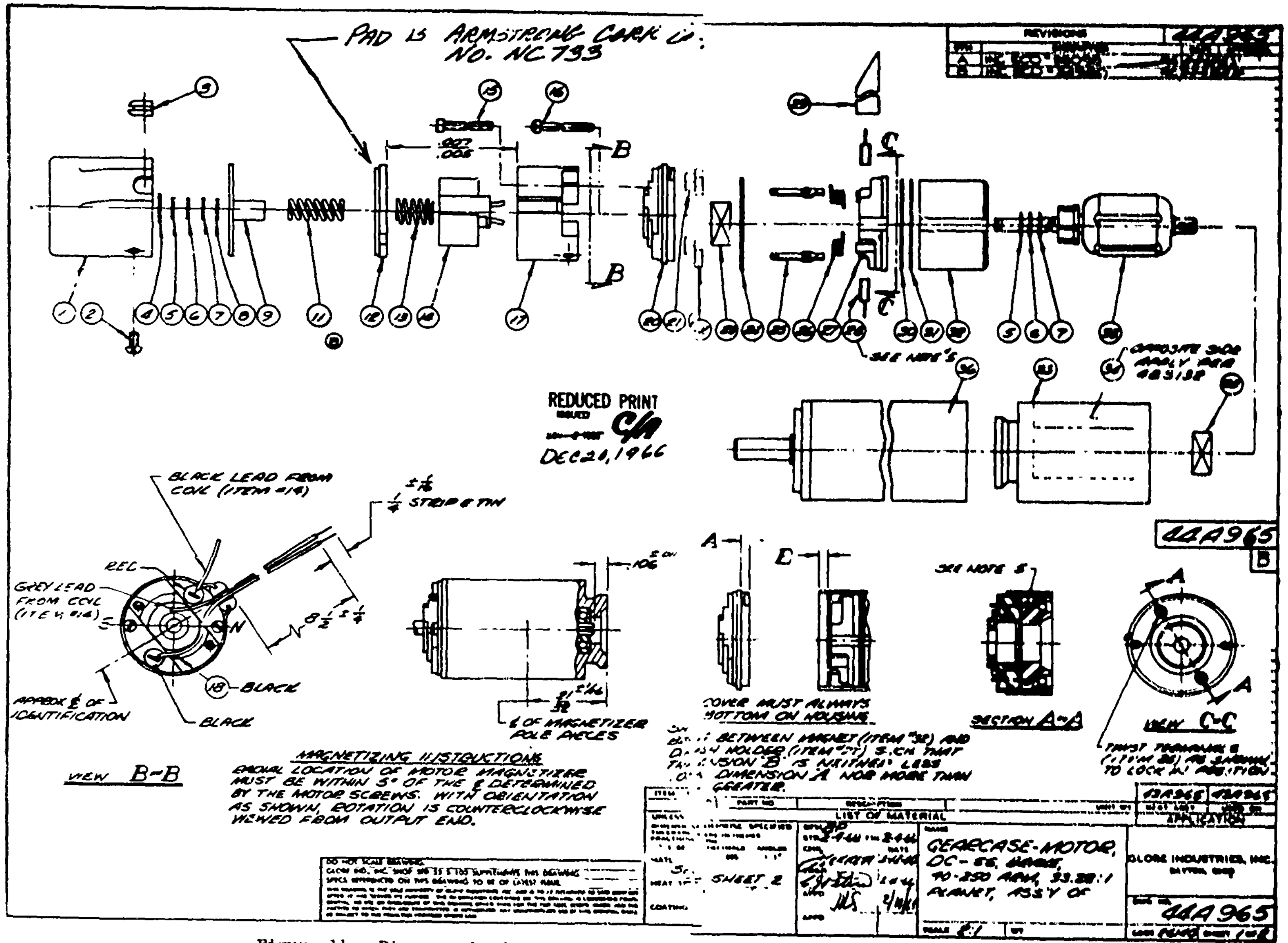

Figure 11. Diagram showing assembly details of Design B ignitor system. (Part II)

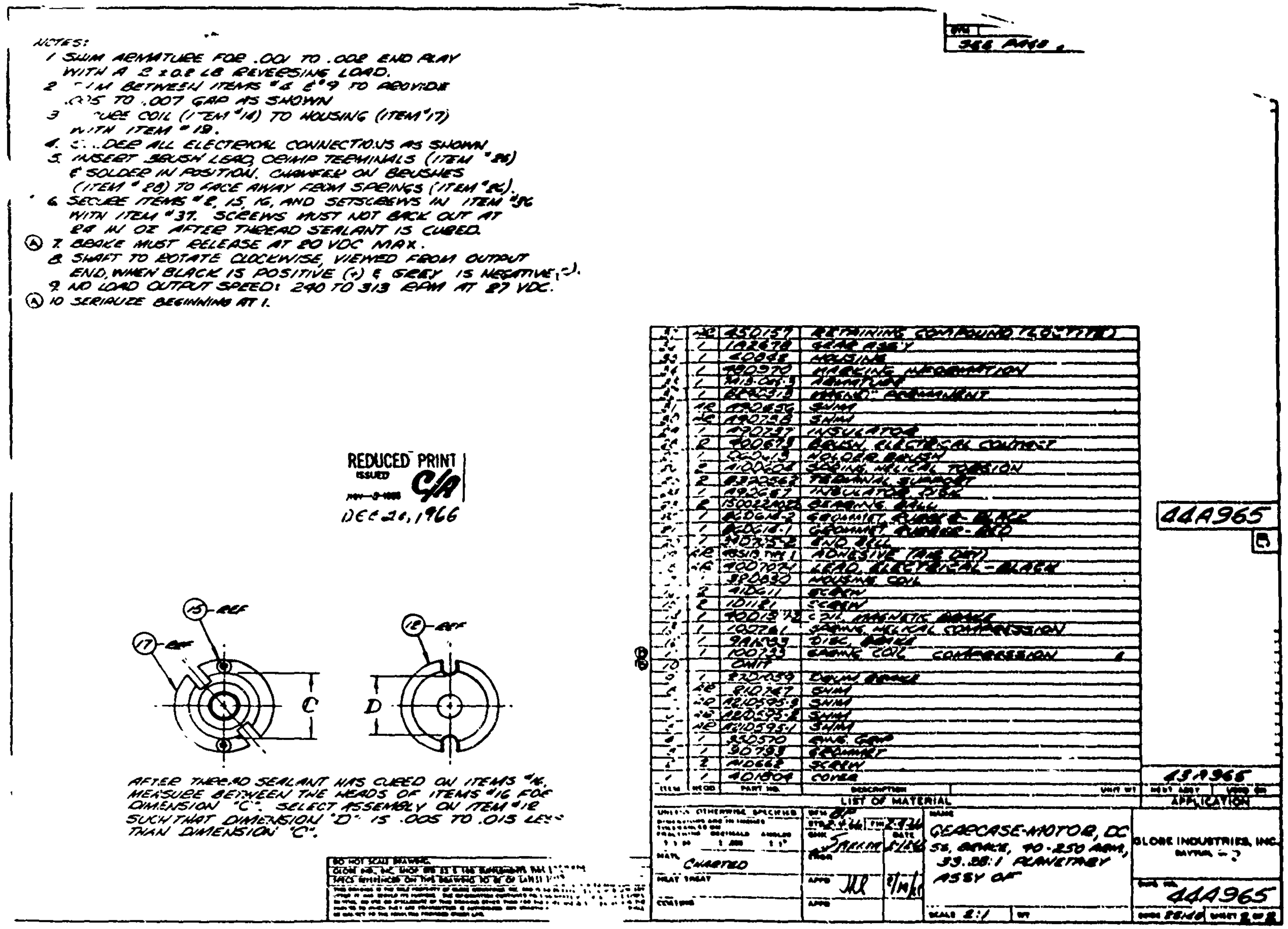

Figure 11. Diagram showing assembly details of Design B ignitor system. (Part III)

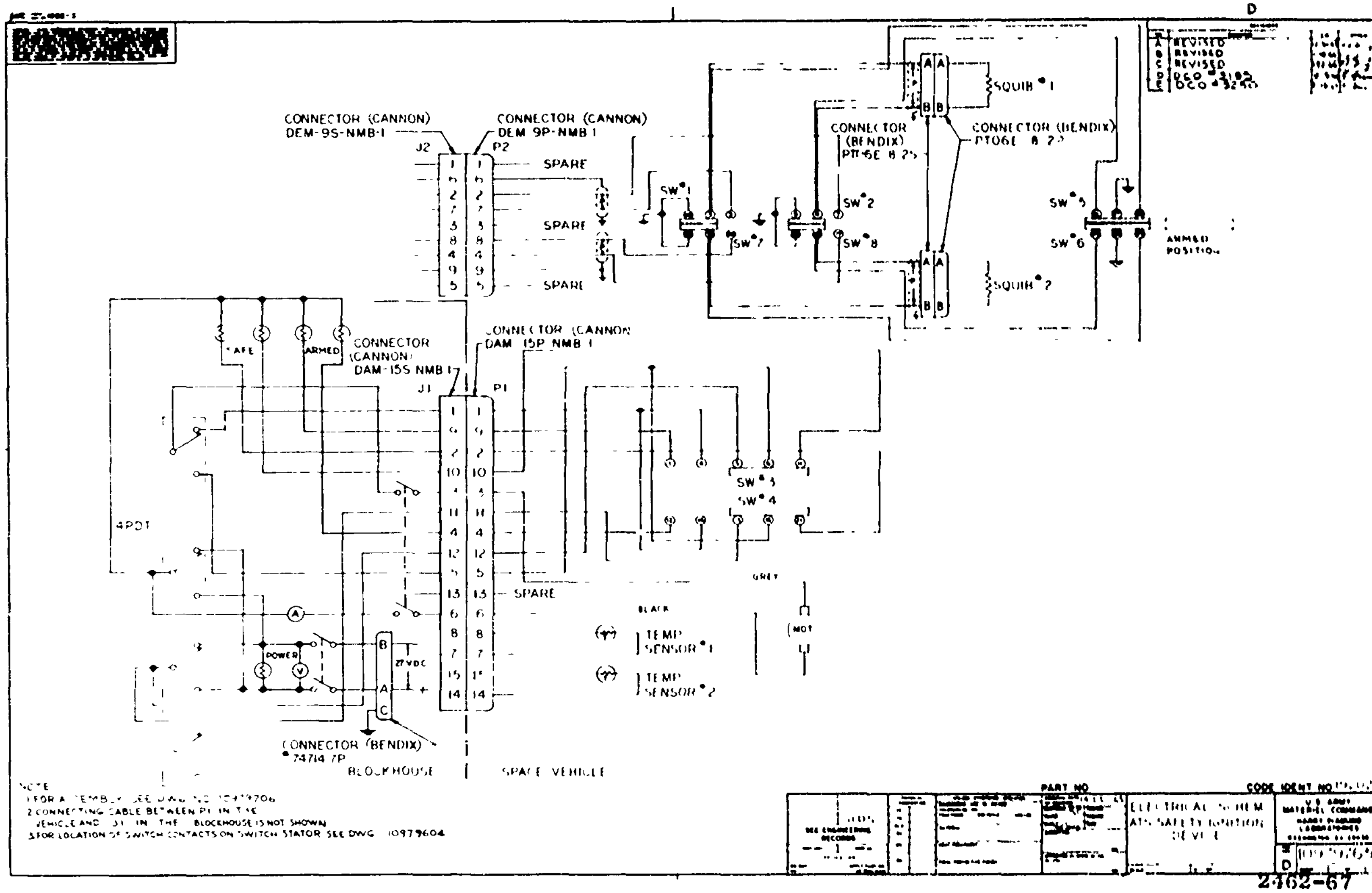

Figure 12. Diagram of Design B switching functions.

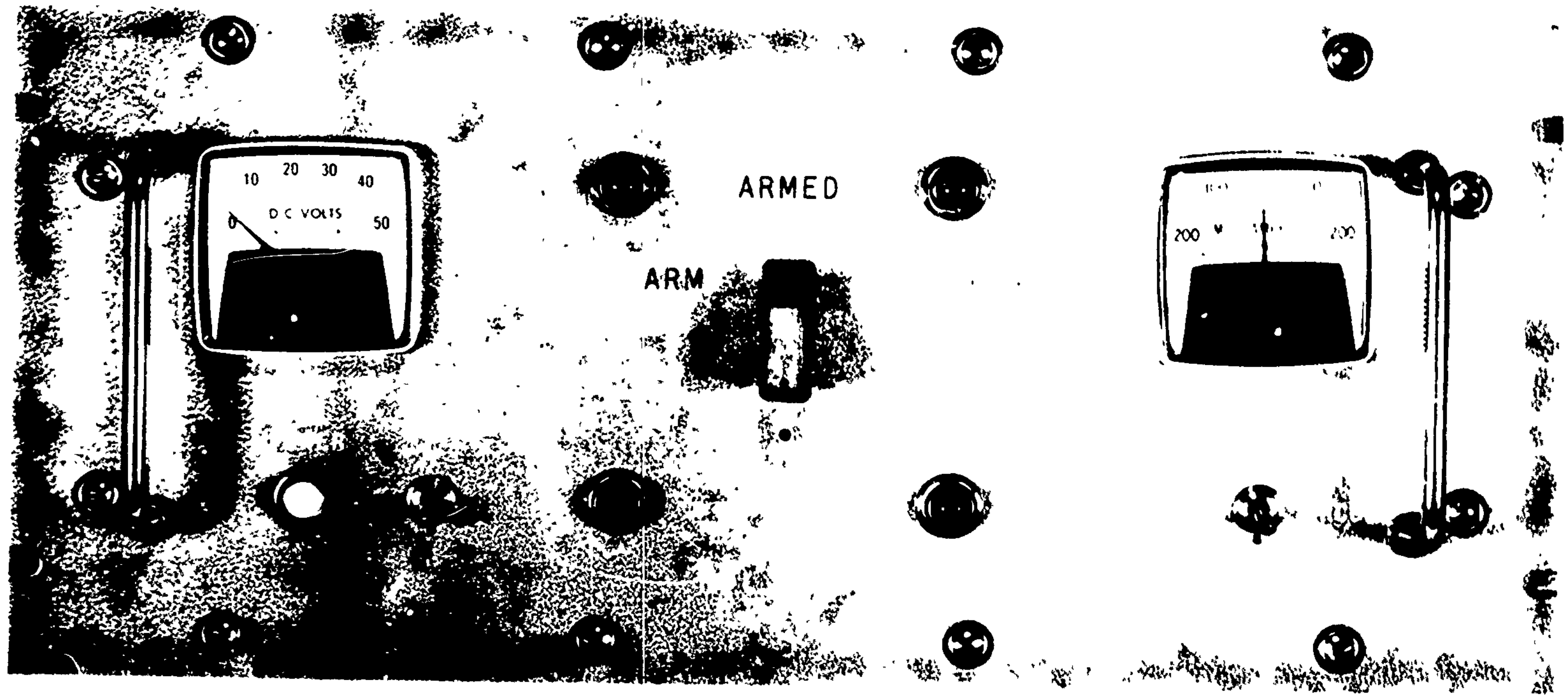

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Figure 13. SID Design E control panel.

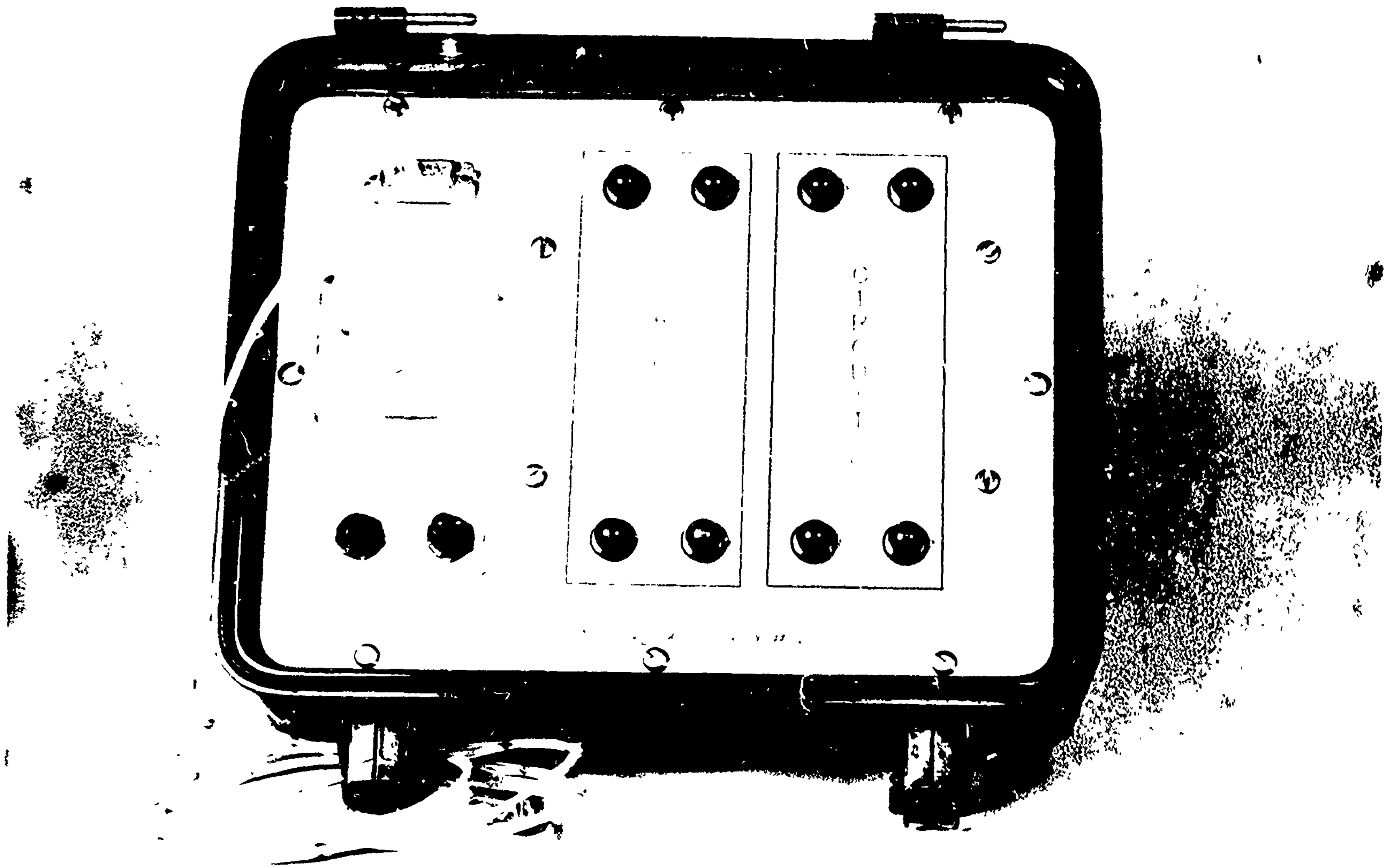

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Figure 14. SID Design B checkout-box panel.

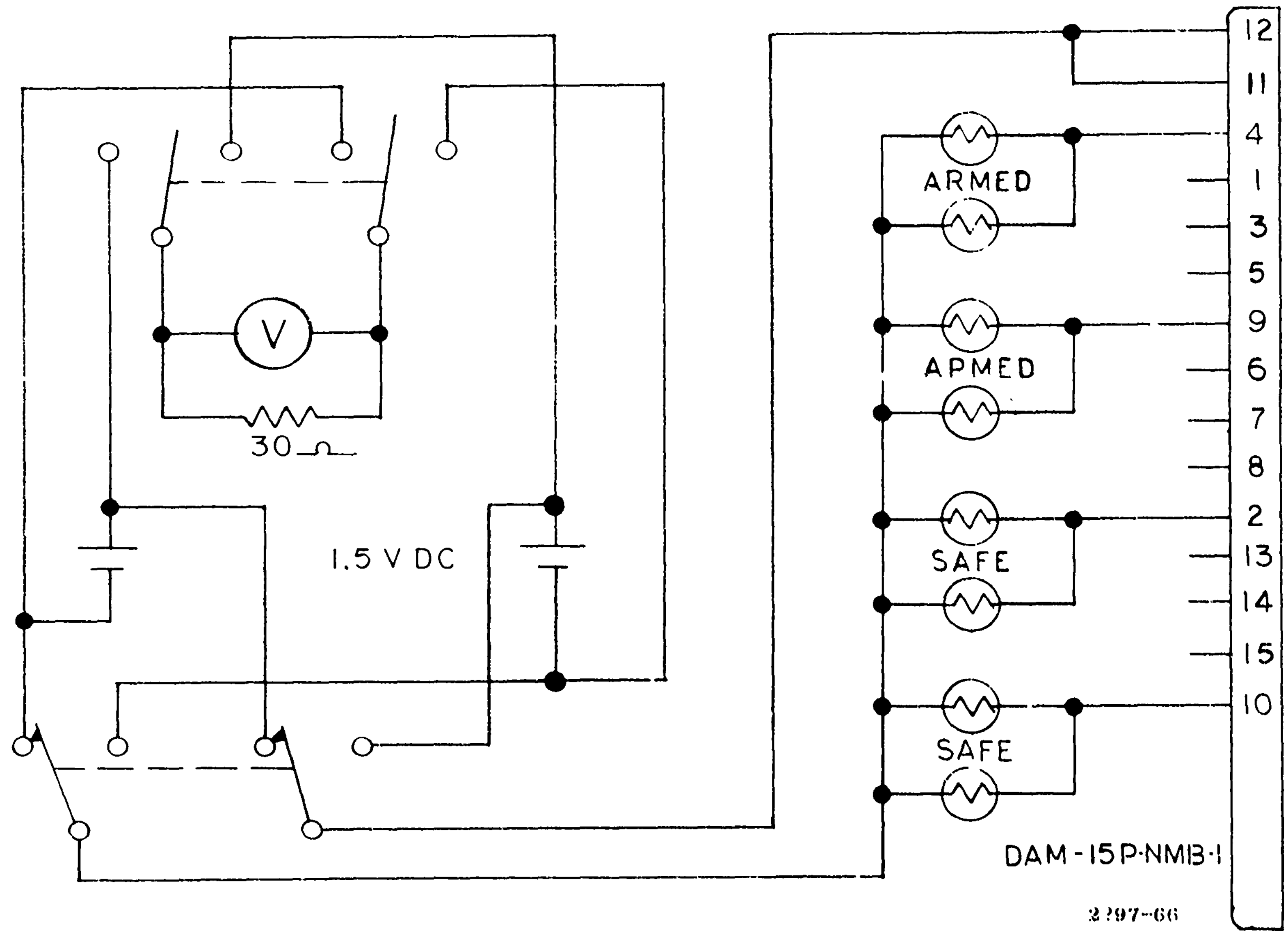


Figure 15. Schematic diagram of Design B checkout box.

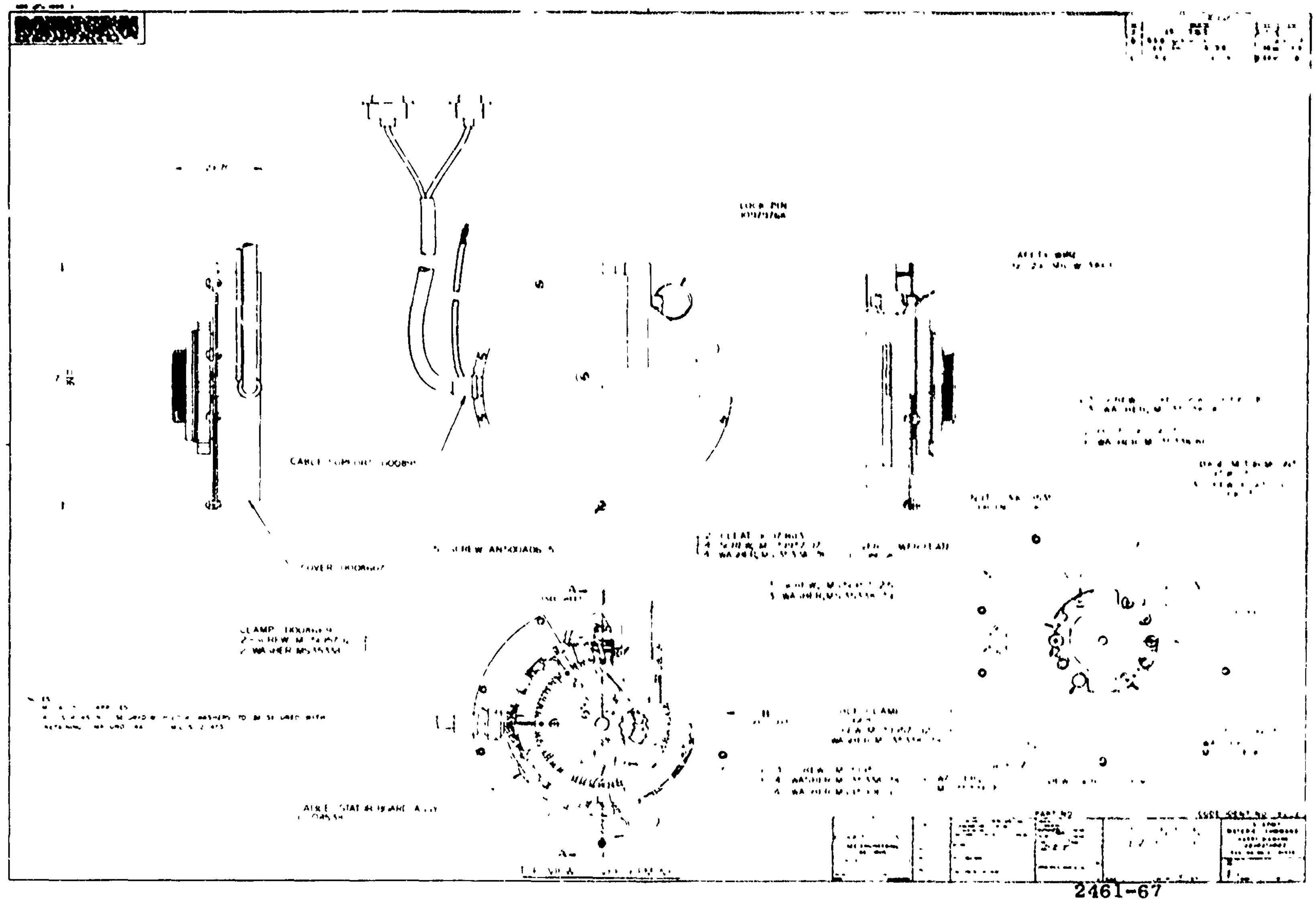


Figure 16. SID Design B—assembly details.

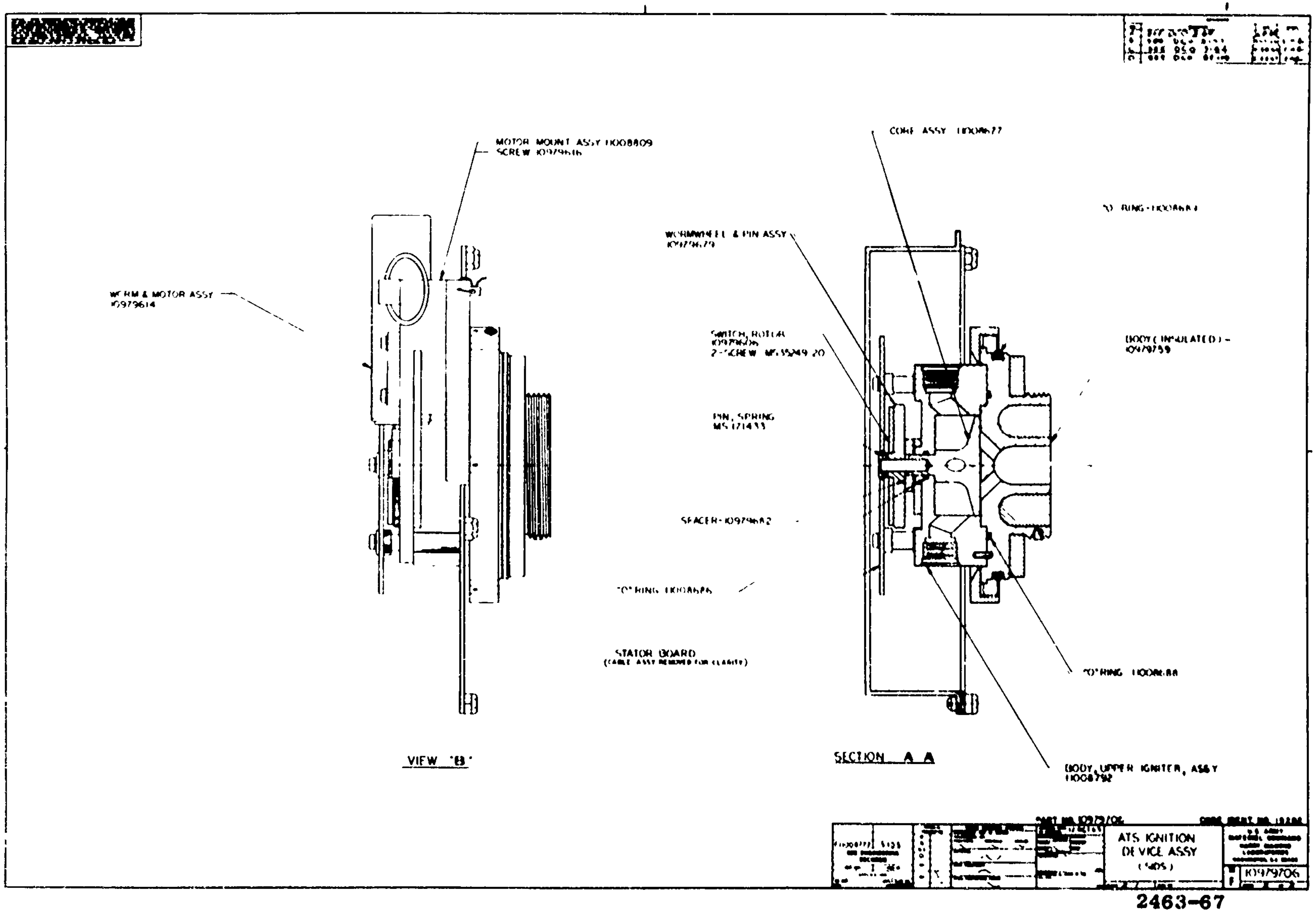


Figure 17. SID Design B—cutaway and assembly drawings.

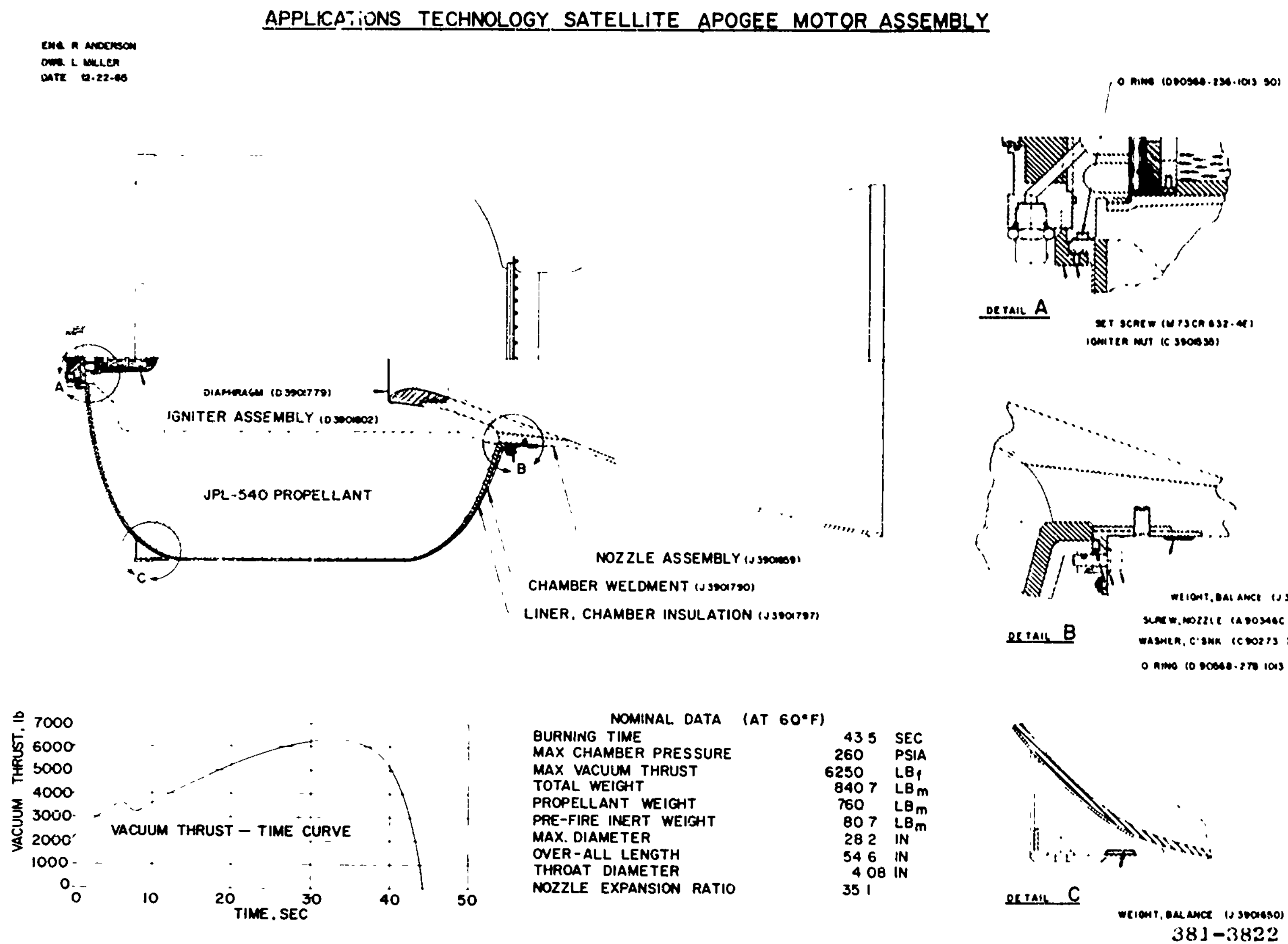
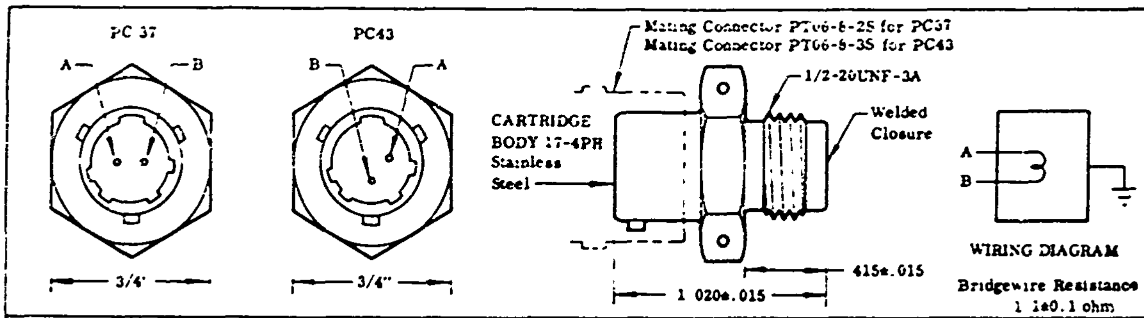
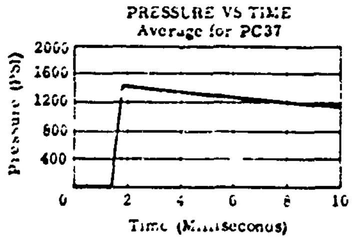
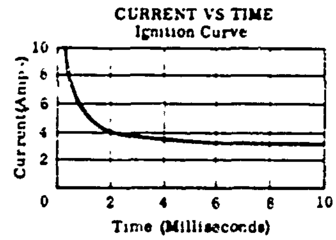


Figure 18. Apogee rocket motor.







QUALIFIED UNDER

AFMTC Ordnance Standard
(1 amp — 1 watt no fire level for 5 minutes)
AFMTCP 80-2 General Range Safety Plan

SPECIFICATION WS2383

PC37 is additionally qualified under the requirements of Thiokol Chemical Corp. Specification SE 1678 for Surveyor retrorocket motor system use near surface of the moon.

1. ① RECOMMENDED FIRING CURRENT
   5 amps applied to one bridgewire or to each bridgewire over a temperature range of -65°F to +165°F results in a 3-millisecond or less function time

2. HIGH ALTITUDE
   Has been tested to and performs satisfactorily at 550,000 feet. Can be expected to perform in conditions approaching a complete vacuum

3. HERMETIC SEAL
   All cartridges are checked at a differential pressure of approximately 10^{-6}mm of Hg for a leakage rate not to exceed 1×10^{-6}cc of Helium per second STP

4. HIGH AND LOW TEMPERATURE
   Has been tested with satisfactory performance in a temperature range of -300°F to +300°F.

5. ① MINIMUM ALL-FIRE CURRENT
   Minimum recommended all-fire current is 3.5 amps to one bridgewire or to each bridgewire at ambient conditions.

6. ENVIRONMENTAL CAPABILITIES

Humidity to:	MIL-STD-304.
Shock:	200 'G' in each of three orthogonal axes.
Vibration to.	MIL-E-5272 in each of three orthogonal axes.
Salt Spray to:	Federal Test Method STD No. 151.

7. ○ NO-FIRE CURRENT
   Cartridges stabilized to +350°F were subjected to 1-amp, 1-watt current applied for 5 minutes to both bridgewires simultaneously and were then fired at ambient temperature without evidence of degradation of performance

8. INSULATION RESISTANCE
   100 megohms minimum insulation resistance when 500 VDC is applied between shorted contact pins and the cartridge body.

9. DIELECTRIC STRENGTH
   Withstands 500 VAC (rms) applied between the contact pins shorted together and the cartridge body for 1 minute without breakdown. No arc-over, breakdown, or a transient increase in leakage current is detectable.

10. ① STATIC SENSITIVITY
    No ignition occurs when a 500-micromicrofarad capacitor charged with 5000 volts is discharged between the contact pins shorted together and the cartridge body at 70°F at ambient pressure

11. RADIO FREQUENCY HAZARDS
    Test samples were exposed to a range of 8 megacycles to 10,000 megacycles with a power input of .10 watts to each bridgewire. All cartridges tested passed without firing or degradation as evidenced by subsequent firing tests.

12. AVERAGE PEAK PRESSURE

Cartridge	PSI (Ambient)	Test Chamber Size (C.C.)
PC37	1325	10.0
PC43	600	10.0

13. UNIT WEIGHT
    The assembled cartridge weighs less than .04 pounds.

U.S. Patent No 3,135,200

NOTICE
[illegible]

CODE IDENTIFICATION NO. 73197

	Date	By
Drawn	12-3-64	Br/ej
Approved	12-9-64	[illegible]
Rev ①	3-10-65	Br/ej

1/2-20 POWER CARTRIDGE
GAS AND HEAT GENERATING

Standards Page Number
2-1720-8E

Cartridge Assembly Part Number
PC37, PC43

Figure 19. Output characteristics of Hi-Shear-37 igniter squib.

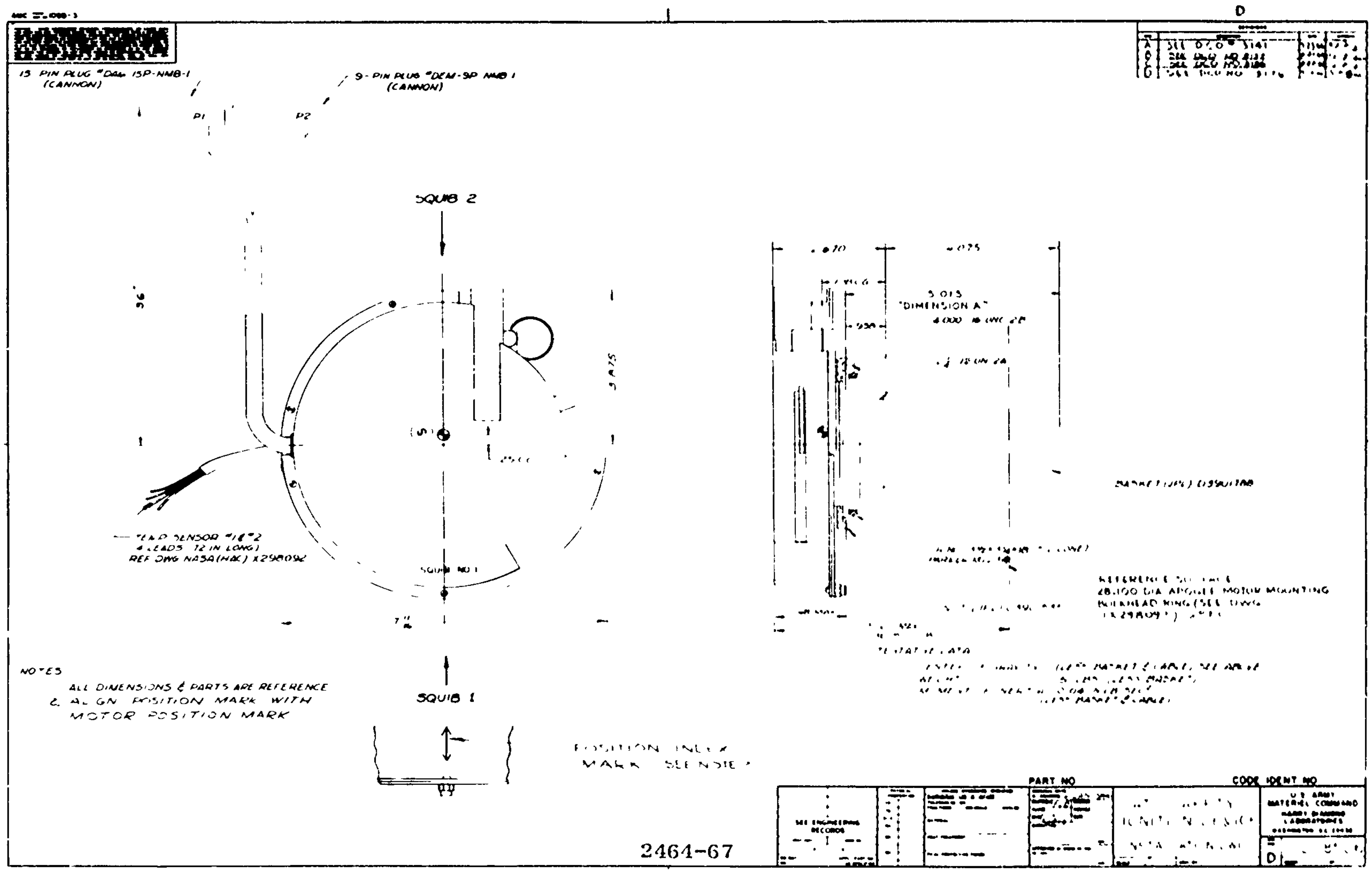


Figure 20. Diagram showing CG and moment of inertia of SID.

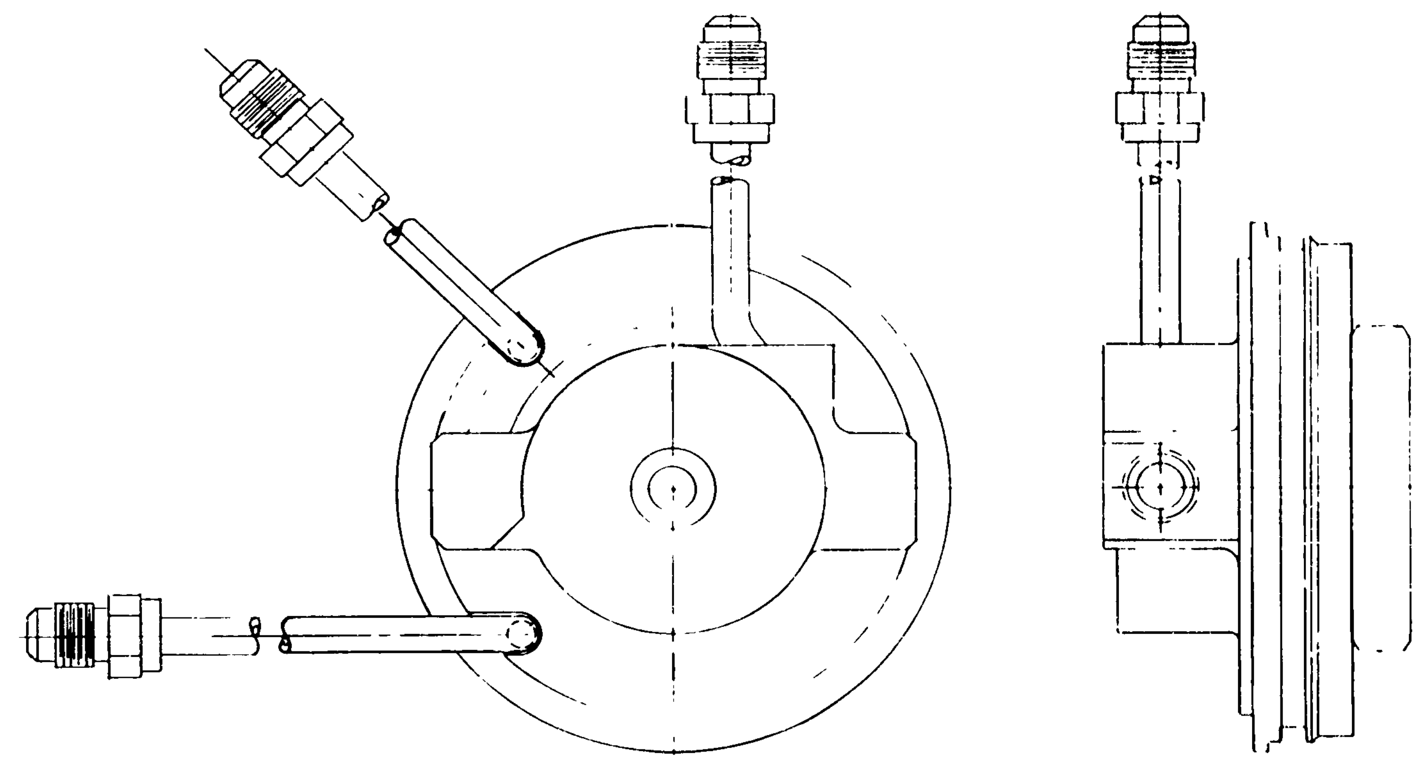


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Figure 21. Diagram showing SID Design B modified for test purpose.

APPENDIX A. — ASSEMBLY DETAILS

All component parts of the safety device were inspected visually for damage and defects before assembly. The procedures followed during assembly of the SID required that the:

(a) Squib ports in the upper body be protected with suitable plastic plugs, and that the plugs and thread on the bottom of the lower body be given similar protection with suitable plastic cups;

(b) Screw heads be inspected at each assembly step described below, and that the screw heads would be replaced if any burring was indicated;

(c) Worm and motor (parts 20 and 24, respectively of fig. 5) would be assembled in the shop before assembling the unit and attached to the cable stator board assembly (part 27) during subassembly; and

(d) Fasteners would be nonmagnetic.

Using the designations shown on figure 5 (body of report), the SID was assembled in the following steps:

Step 1. —Assemble parts 5 (core) and 7 (shaft) with part 6 (roll pin), and apply Molykote to base of core.

Step 2.— Assemble parts 8 (upper body) and 12 (O-ring), taking care not to damage the O-ring.

Step 3.— Assemble part 8 (upper body) (8 and 12) with part 5 (core 5, 6, and 7), being careful not to damage O-ring.

Step 4.— Apply Molykote to center section of Part 2 (lower body).

Step 5. —Assemble parts 2 (lower body), 3 (O-ring), 4(closure nut), 17 (base, motor mount), 8 (upper body), and 5, 6, and 7 (core assembly) with 9 (lockwasher) and 10 (stud), 10a (stud), 11 (screw) and torque to 40 in.-lb. (Units to be hydrostatically tested were removed after this step.)

Step 6. —Remove squib cavity plugs and base-thread guard. Install test squib plug and assembly to pressure-check fixture (HDL drawing C1109012). Unit must not lose pressure in 30 min. Remove unit

from fixture and remove test-squib plugs. Replace thread guard and plastic plugs.

Step 7.— Assemble parts 13 (cover base) and 14 (cable support).

Step 8.— Assemble part 13 (cover base) (13 and 14) to tested units.

Step 9.— Assemble parts 21 (pin) and 22 (worm wheel), and stake 21 (worm-wheel pin) after it has been screwed into place.

Step 10.—Assemble parts 10 (lever), 16 (spacer), 18 (motor mount), and 19 (screw) on unit. Assemble parts 22 (worm wheel) (21 and 22) with 22a (pin), taking care as it can be assembled in two ways. With parts 15 (lever) on counterclockwise, part 22 (worm wheel) should be able to rotate on part 7 (shaft) 180 deg without moving part 15 (manual safing lever). The worm wheel (22) is now rotated until it is in line with the hole in part 6 (core assembly) and the pin (22a) is pressed into place. Moving the manual safing lever (15) as far as it will go clockwise puts the unit in the safe position.

Step 11.—Inspect for ports closed in safe position. Then inspect for opened and aligned parts in the armed position, making sure that parts 15 (lever) and 18 (motor mount) move freely without drag. There must be no indication of wear on parts 15 and 18 in five of six times of testing. Approval inspection for this step must be given by assembly supervisor.

Step 12.—Add parts 26 (switch rotor) to 22 (worm wheel) with the screws provided. After the inspection for this step, parts 27 (cable stator board) will be added and 14a (clamp) put in place.

APPENDIX B.— SID ELECTRICAL CHECKOUT -- Procedure I.

A. With the unit in the safe position and connectors P1 and P2 disconnected, check each of the 28 terminals as follows:

STATOR BOARD TERMINAL NUMBERS

1. (a) Continuity with pin 9 of connector P1.

(b) Open circuit with all other terminals and all other pins of connector P1 and P2 and ground.

2. (a) Continuity with pin 7 of connector P2.

(b) Open circuit with all other terminals and all other pins of connectors P1 and P2.

(c) Open circuit with ground.

3. (a) Continuity with Pins 6 and 9 of connector P2.

(b) Continuity with terminals 8, 9, 10, 13, 18, 19, 22, 23, 24, 25, 26, 27, 28, and ground.

(c) Continuity with pins A and B of squib connectors 1 and 2.

4. (a) Continuity with pin 1 of connector P1.

(b) Continuity with terminal 14.

(c) Open circuit to all other terminals, all pins of connectors P1 and P2 and ground.

5. (a) Continuity with pin 2, 5, 10, 11, and 12 of connector P1.

(b) Continuity with terminals 6, 11, 15, 16, and 21.

(c) Open circuit with all other terminals, all other pins of connectors P1 and P2 and ground.

6. (a) Continuity with pins 2, 5, 10, 11, and 12 of connector P1.

(b) Continuity with terminals 5, 11, 15, 16, and 21.

(c) Open circuit with all other terminals, all other pins of connectors P1 and P2 and ground.

7. (a) Continuity with pin 2 of connector P2.

(b) Open circuit with all other terminals, all other pins of connectors P1 and P2 and ground.

8. (a) Continuity with pins 6 & 9 of connector P2.

(b) Continuity with terminals 3, 9, 10, 13, 18, 19, 22, 23, 24, 25, 26, 27, 28, and ground.

(c) Continuity with pins A and B of squib connectors 1 and 2.

9. (Same as 3 and 8.)

10. (Same as 3 and 8.)

11. (a) Continuity with pin 2, 5, 10, 11, and 12 of connector P1.

(b) Continuity with terminal 5, 6, 11, 15, 16, and 21.

(c) Open circuit all other points.

12. (a) Continuity with pin 4 of connector P1.

13. (Same as 3, 8, 9, and 10.)

14. (a) Continuity with terminal 4 and pin 1 of connector P1.

(b) Open circuit with all other points.

15. (a) Continuity with pins 2, 5, 10. 11 and 12 of P1.

(b) Continuity with terminals 5, 6, 11, 16, and 21.

(c) Open circuit with all other points.

16. (Same as 15.)

17. (a) Continuity with pin 4 of connector P2.

(b) Open circuit with all other points.

18. (Same as 3, 8, etc.)

19. (Same as 3, 8, etc.)

20. (a) Continuity with pin 8, connector P2.

(b) Open circuit with all other points.

21. (a) Continuity with pins 2, 5, 10, 11, and 12 of connector P1.

(b) Continuity with terminals 5, 6, 11, 15, and 16.

(c) Open circuit with all other terminals, all other pins of connectors P1 and P2 and ground.

22. (Same as 3.)

23. (Same as 3.)

24. (Same as 3.)

25. (Same as 3.)

26. (Same as 3.)

27. (Same as 3.)

28. (Same as 3.)

B. With the unit in the armed position and connector P1 disconnected, check each of the 28 terminals as follows:

STATOR BOARD TERMINAL NUMBERS

1. (a) Continuity with terminals 4, 5, 12, 14, and 15.

(b) Continuity with pins 1, 4, 9, 11, and 12 of connector P1.

2. (a) Continuity with terminals 3 and 28.

(b) Continuity with pin A, squib No. 1.

(c) Continuity with connector P2, pin 7.

(d) Open circuit all other points.

3. (a) Continuity with terminals 2 and 28.

(b) Continuity with pin 7 of connector P2.

(c) Continuity with pin A, Squib No. 1.

(d) Open circuit all other points.

4. (a) Continuity with pins 1, 9, 11, 12, and 4 of connector P1.

(b) Continuity with terminals 1, 5, 12, 14, and 15.

(c) Open circuit with all other points.

5. (Same as 4.)

6. (a) Continuity with pin 5 of connector P1.

(b) Continuity with terminal 16.

(c) Open circuit with all other points.

7. (a) Continuity with pin 2 connector P2.

(b) Continuity with terminals 8 and 26.

(c) Continuity with pin B of squib connector No. 1.

(d) Open circuit with all other points.

8. (Same as 7.)

9. (a) Continuity with pins 6 and 9 of connector P2.

(b) Continuity with terminals 10, 13, 19, 24, 27 and ground.

(c) Open circuit with all other points.

10. (a) Continuity with pins 6 and 9 of connector P2.

(b) Continuity with terminals 9, 10, 13, 19, 24, 27 and ground.

(c) Open circuit with all other points.

11. (a) Continuity with pin 10 of connector P1.

(b) Open circuit with all other points.

12. (a) Continuity with pins 1, 4, 9, 11, and 12 of connector P1.

(b) Continuity with terminals 1, 4, 5, 14, and 15.

(c) Open circuit with all other terminals and all other pins of connector P1 and P2 and ground.

13. (Same as 10.)

14. (Same as 1 and 12.)

15. (a) Continuity with pins 1, 4, 9, 11, and 12 of connector P1.

(b) Continuity with terminals 1, 4, 5, 12, and 14.

(c) Open circuit with all other terminals, and all other pins of connector P1 and P2 and ground.

16. (a) Continuity with pin 5 of connector P1.

(b) Continuity with terminal 6.

(c) Open circuit with all other terminals, all other pins of connectors P1 and P2 and ground.

17. (a) Continuity with pin 4, of connector P2.

(b) Continuity with terminals 18 and 25.

(c) Continuity with pin A, squib connector 2.

(d) Open circuit with all other points.

18. (Same as 17.)

19. (a) Continuity with pins 6 and 9 of connector P2.

(b) Continuity with terminals 9, 10, 13, 24, 27, and ground.

(c) Open with pins A and B of squib connectors 1 and 2.

20. (a) Continuity with pin 8 of connector P2.

(b) Continuity with terminals 22 and 23.

(c) Continuity with pin B squib connector No. 2.

(d) Open circuit all other points.

21. (a) Continuity pin 2, connector P1.

(b) Open circuit all other points.

22. (Same as 20.)

23. (Same as 20.)

24. (a) Continuity with pins 6 and 9 of connector P2.

(b) Continuity with pins 9, 10, 13, 19, 27, and ground.

(c) Open circuit with all other points.

25. (a) Continuity with pin A of squib connector No. 2.
    (b) Continuity with pin 4 of connector P2.
    (c) Continuity with terminals 17 and 18.
    (d) Open circuit with all other points.

26. (a) Continuity with pin B of squib connector No. 1.
    (b) Continuity with pin 2 of connector P2.
    (c) Continuity with terminals 7 and 8.
    (d) Open all other terminals and ground.

27. (Same as 24.)

28. (a) Continuity with pin A, squib connector No. 1.
    (b) Continuity with pin 7 of connector P2.
    (c) Continuity with terminals 2 and 3.
    (d) Open all other terminals and ground.

APPENDIX C. — SID SWITCH CIRCUIT CONTACT RESISTANCE CHECKOUT— Procedure II.

GENERAL

1. This test is performed to determine any corrosion or incorrect pressure of individual contacts of the motor, indicator light, and squib firing switching circuits.

2. The following HDL drawings are required for this checkout:

(A) Electrical Schematic ATS Safety-Ignition Device: D10979765.

(B) Cable-Stator Board Assy: D11008538.

3. Resistance readings to be taken with an impedance bridge (General Radio Co., Type 1650A or equal).

PROCEDURE

1. SID unit to be cycled to SAFE (S) position. Connector P1 and P2 to be disconnected from all power sources. All shorting plugs removed.

2. Connector P1 (DAM-I5P-NMB-1) and PIN numbers as indicated to be connected to impedance bridge and resistance readings taken as follows:

A. SAFE POSITION, Connector P1

Pin to Pin	Approximate Resistance (ohms)
12-5	.12
12-10	.12
10-5	.12
11-5	.12
5-2	.12
11-2	.12

B. MOTOR CIRCUIT, Connector P1

Pin to Pin	Approximate Resistance (ohms)
3-6	55

3. Disconnect impedance bridge and cycle SID to ARM (A) position. Connect impedance bridge to pins on connector P1 (DAM-15P-WMB-1) and make resistance readings as follows:

A.

Pin to Pin	Approximate Resistance (ohms)
12-1	.12
12-9	.12
1-9	.12
11-1	.12
1-4	.12
11-4	.12

4. SIDS Unit in ARM (A) position.

Connect impedance bridge to connector P2 (DEM-9P-NMB-1) and make resistance readings as follows:

A. Short squib connector No. 1 pins A and B. Short squib connector No. 2 pins A and B.

Pin to Pin	Approximate Resistance (ohms)
2-7	.13
4-8	.13

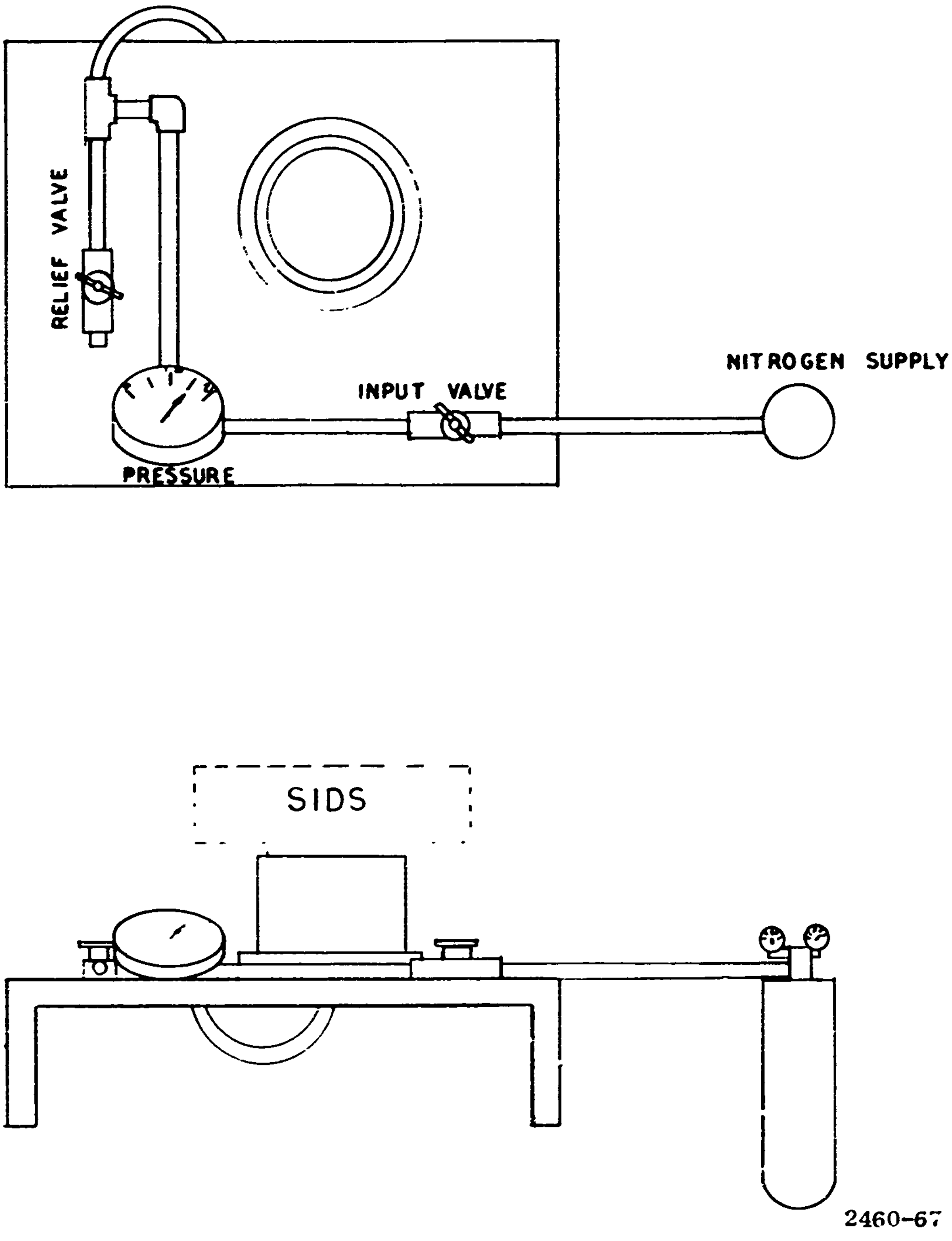

Figure C-1. Low pressure test setup.

APPENDIX D. —SAFING AND ARMING UNIT OPERATIONS

1. Inspection and Checkout Procedure for ATS Safety Ignition Device (SIDS) (for use at Eastern Test Range).

General

1. All Safety-Ignition Device activity described in this procedure will occur in the Cape Kennedy Solid Propellant Area Test Shed.

2. Personnel working with or around SID's will observe safety procedures and use protective equipment as specified in this document.

Equipment

1. Safety Glasses.

2. Smocks, flame-proof, static-free cloth (Government Furnished).

3. Ground-straps (Leg-stats).

4. Eight HI-SHEAR CORP. PC-37 Power Cartridges (squibs) (HDL supplied).

5. Two SIDS (HDL P/N F10979706) delivered, procedure applies to both.

6. Four HI-SHEAR CORP. PC-37 Inert Power Cartridges (squibs) with bridgewires (HDL supplied).

I. SID INSPECTION PROCEDURE

1. UNPACK. Remove SID's from shipping containers.

2. Observe letter (S) in Arm-Safe Window. Reference: Dwg F10979706, ATS Ignition Device (SIDS).

3. Visually check for shipping damage.

4. CHECK AND VERIFY THAT SID IS INERT. (No live squibs installed.)

5. Using inert SID's, perform switch circuit resistance and the port alignment check (see procedure A of this appx).

6. Using inert SID's, perform insulation resistance test (see procedure of this appx).

7. Measure and record resistance of the four inert squib bridgewires with the Solids Area Alinco meter.

Inert squib S/N __________ ____________________ohm

Inert squib S/N __________ ____________________ohm

Inert squib S/N __________ ____________________ohm

Inert squib S/N __________ ____________________ohm

8. Remove cover from SID's and install two inert squibs in each of the SIDS. Torque squibs to 110 in. lb ±10 in.-lb. Record squib serial numbers and SID serial numbers. Replace cover on SID's.

9. Remove protective cover from base of SID's and attach SID's to HDL leak test fixture.

10. Arm one SID with the HDL control panel D11008530. Pressurize device with 15 psig and seal off. (NOTE: Input N_2 to be removed after SID is pressurized.)

11. Record pressure and time at 10-min intervals. Pressure should not drop over a 1/2-hr interval.

12. Release pressure from SID's and remove SID's from leak test fixture.

13. Repeat steps (9) through (12) for second SID.

14. Measure and record the inert squib bridge wire resistance through the SID P-2 connector (refer to HDL drawing 10979765). The resistance reading should be made with the Solids Area Alinco meter.

SID S/N ____________

Pins 2 to 7 (inert squib 1, S/N __________) ____________ohms

Pins 4 to 8 (inert squib 2, S/N __________) ____________ohms

SID S/N ____________

Pins 2 to 7 (Inert squib 1, S/N __________) ____________ohms

Pins 4 to 8 (inert squib 2, S/N __________) ____________ohms

15. Return both SID's to the safe position with HDL control panel 11008530. Both SIDS are now ready for Electrical Compatibility Check with ATS Spacecraft.

II. SQUIB INSPECTION PROCEDURE

1. Unpack four PC-37 squibs from shipping containers. NOTE: Squibs are to be left in HDL safety containers (HDL drawing No. C1100-9188) during all electrical checks.

2. Using Solids Area Alinco meter (or equivalent), measure and record squib bridgewire resistances.

	Squib Pin A to B
Squib S/N __________	__________ ohms
Squib S/N __________	__________ ohms
Squib S/N __________	__________ ohms
Squib S/N __________	__________ ohms

Resistance readings should be 1.1 ± 0.1 ohms.

3. Using Solids Area Megohmeter (Gen. Radio 1862-B with current limited to less than 20 mA) perform a d-c insulation resistance test on each squib. A potential of 500 Vdc should be applied between squib contact pins shorted together and cartridge body for 1 min minimum. The measured insulation resistance should be greater than 100 megohms.

4. Squibs are now ready for installation in the SIDS.

III. SQUIB INSTALLATION PROCEDURE

1. Remove inert squibs from both SIDS.

2. Install one SIDS on the HDL steel fixture (HDL drawing C11008823). NOTE: Only one SIDS will have live squibs installed in it. The other SIDS will be placed in storage until needed. Check that SIDS is in the safe position. If in armed position return safe with HDL control panel D11008530.

3. Remove cover from SIDS and install two (2) HI-SHEAR PC-37 squibs in the SIDS device. Shorting caps should be on the squibs during installation. Torque squibs to 110 ± 10 in.-lb. Record serial numbers with respective squib number assignment.

SIDS S/N ______________

Squib 1 Squib S/N ________

Squib 2 Squib S/N ________

4. Safety wire squibs to SID post 11008617.

5. Check that shorting plug is installed in SID connector P-2.

6. Prior to connecting squib connectors to the squibs, perform the electrical check as specified in Procedure C of this appendix.

7. Install shorting connector on P-2 and P-1.

8. Remove squib shorting plugs from back of squibs and connect the SID squib connectors to the squibs.

9. Verify SID's in SAFE POSITION.

10. Check that squib connectors are in place (Reference HDL F10979706) and that squibs are safety wired in place.

11. Install SID covers.

12. Remove shorting plug from cable connector (P1) and connect P1 to HDL control panel. Reference: Drawing 11008530, Control Panel Assy and Drawing D1108817, ATS ignition device system.

13. Using HDL control panel, D11008530, electrically cycle the unit to ARM. Observe letter (A) in window of unit. Remove P1 from control panel. Reinstall shorting plug.

14. Remove shorting plug from SID cable connector P2, (DEM-9P-NMB-1). Connect P2 to Solids Area Alinco meter. Measure and record the squib bridge wire resistances through the P2 connector.

SIDS S/N ______________

Pins 2 to 7 (Squib 1, S/N __________) __________ohms

Pins 4 to 8 (Squib 2, S/N __________) __________ohms

Correct above readings for contact resistance readings made in Procedure A for actual squib bridgewire resistance. Squib bridgewire resistance should be 1.1 ± .1 ohms.

15. Install shorting plug on connector P2.

16. Remove shorting plug from connector P1 and connect to control panel Cycle (SIDS) unit to SAFE. Observe letter (S) in window of unit.

17. Remove (SIDS) unit from steel fixtuie.

18. Remove protective cover from the base of the SID and attach SID to HDL leak test fixture.

19. Pressurize device with 15 psig and seal off (NOTE: Input N_2 to be removed after SIDS is pressurized).

20. Record pressure and time at 10-min intervals. Pressure should not drop over a 1/2-hr interval.

21. Release pressure from SID's and remove SID's from leak test fixture.

22. SID's should be weighed on a gram balance scale (or equivalent) to the nearest gram. Record weight.

SIDS S/N ____________________ ____________________lbs

This completes inspection and checkout of SAFETY-IGNITION DEVICE.

APPENDIX D (Cont'd).— SWITCH CIRCUIT CONTACT RESISTANCE CHECK-OUT AND SQUIB PORT ALIGNMENT CHECK.

Procedure A.

General:

1. This test is performed to determine any corrosion or incorrect pressure of individual contacts of the motor, indicator light, and squib firing switching circuits and to check squib rotor port alignment.

2. The following HDL drawings are required for this checkout:

a. Electrical Schematic ATS Safety Ignition Device: D10979765.

b. Cable-Stator Board Assy: D11008538.

c. HDL Control Panel Assy: D11008530.

3. Resistance readings to be taken with an impedance bridge, (General Radio Co., Type 1650 A, or equal).

PROCEDURE:

1. SID's should be in the SAFE (S) position. Connector P1 and P2 to be disconnected from all power sources. All shorting plugs removed.

2. Connector P1 (DAM-15P-NMB-1) PIN numbers as indicated to be connected to impedance bridge and resistance readings to be recorded as follows:

A. SAFE POSITION

Connector P1 Pin to Pin	RESISTANCE SIDS S/N________	SIDS S/N______
12-5	________ohms	________ohms
12-10	________ohms	________ohms
10-5	________ohms	________ohms
11-5	________ohms	________ohms
5-2	________ohms	________ohms
11-2	________ohms	________ohms

Above resistance readings to be compared with those made on units by HDL at HDL.

B. MOTOR CIRCUIT, Connector P1

Pin to Pin	SIDS S/N ________	SIDS S/N ____
3-6	____________ohms	________ohms

Above resistance readings to be compared with those made on units by HDL at HDL.

3. Disconnect impedance bridge and cycle SID to ARM (A) position with HDL panel D11008530. Connect impedance bridge to pins on connector P1 (DAM-15P-NMB-1) and make resistance readings as follows:

A. Pin to Pin	RESISTANCE SIDS S/N ________	SIDS S/N ______
12-1	______________ohms	__________ohms
12-9	______________ohms	__________ohms
1-9	______________ohms	__________ohms
11-4	______________ohms	__________ohms
1-4	______________ohms	__________ohms
11-4	______________ohms	__________ohms

Above resistance readings are to be compared with those made on units by HDL at HDL.

4. SID's in ARM (A) position.

Connect impedance bridge to connector P2 (DEM-9P-NMB-1) and make resistance readings as follows:

A. Short squib connector No. 1 pins A and B. Short squib connector No. 2 pins A and B.

Pin to Pin	RESISTANCE SIDS S/N_________	SIDS S/N______
2-7	______________ohms	__________ohms
4-8	______________ohms	__________ohms

Above resistance readings are to be compared with those made on units by HDL at HDL.

5. Using suitable inspection lamp sight through port in base of SIDS to insure that squib rotor ports are properly aligned (the ports in the rotor should be concentric with ports in the lower body; refer to HDL drawings D11008612, C10979703.

6. Return SID's to the safe condition with HDL panel D11008530. While unit is being cycled, record current drawn by SID motor as indicated by ammeter on control panel. Current should not exceed 190 mA.

SIDS S/N ________________ ____________________mA

SIDS S/N ________________ ____________________mA

7. Return SID's to the armed condition with HDL panel D11008530. While unit is being cycled, record current drawn by SID motor as indicated by ammeter on control panel. Current should not exceed 190 mA.

SIDS S/N ________________ ____________________mA

SIDS S/N ________________ ____________________mA

8. Repeat steps 5 through 7 for the second SID.

SIDS INSULATION RESISTANCE TEST
Procedure B

1. The purpose of this test is to determine if there is insulation breakdown between the squib signal and return leads on the SID. There are no squibs required for this test. The test will require the use of the Solids Area Megohmeter (Gen. Radio 1862-B with current limited to less than 20 mA).

2. SID's to be inert (no squibs installed) and in the armed position.

3. Connect megohmeter to SID connector P2.

4. Using megohmeter, place 500 Vdc across pins 2 and 7 on P2 for at least 30 sec. Resistance readings should be 100 megohms or greater.

5. Using megohmeter, place 500 Vdc across pins 4 and 8 on P2 for at least 30 sec. Resistance reading should be 100 megohms or greater.

6. Repeat steps 3 through 5 for second SID.

7. Return both SID's to safe position with the HDL control panel D11008530.

SIDS ELECTRICAL CHECK
Procedure C

1. Check that shorting plugs are installed in the back of squibs before proceeding with this test. Unit is to be installed on the HDL steel fixture C11008823.

2. Remove shorting connector from SIDs cable connector P1.

3. Connect P1 to HDL control panel D11008530.

4. Connect an ac-dc voltmeter to squib connector No. 1. Set voltmeter for 0 to 3 Vdc range.

5. Remove shorting plug from connector P2 on the SID's.

6. Using HDL control panel D11008530, electrically cycle the SID's from safe to arm. Observe the voltmeter during this operation. No voltage should be recorded during the cycling operation.

7. Using HDL control panel D11008530, electrically cycle the SID's from arm to safe. Observe voltmeter during this operation. No voltage should be recorded during the cycling operation.

8. Set ac-dc voltmeter for 0 to 3 volts ac and repeat step 6 and 7.

9. Remove ac-dc voltmeter from squib connector No. 1 and connect it to squib connector No. 2.

10. Set voltmeter for 0 to 3 volts dc and repeat steps 6 and 7.

11. Set voltmeter for 0 to 3 volts ac and repeat steps 6 and 7.

12. Disconnect voltmeter from squib connector No. 2.

13. Remove P1 from HDL control panel.

14. Verify that unit is in the safe position by observing (S) Safe in window of SIDs.

15. Unit is now ready for installation of squib connectors.

UNCLASSIFIED

Security Classification

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DESIGN AND THEORY OF OPERATION—SAFETY-IGNITION DEVICE FOR APPLICATIONS TECHNOLOGY SATELLITE ROCKET MOTOR

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13. ABSTRACT

This report describes and illustrates the design and operation of a safety-ignition device (SID) that was developed for use with a 750-lb solid-propellant apogee rocket motor (designed by the Jet Propulsion Labs). This device, used in combination with the Applications Technology Satellite for NASA, is primarily intended to prevent ignition of the rocket motor during ground handling and prelaunch operations, and in orbital flight provide reliable ignition of the apogee rocket motor with a high degree of safety and operational reliability.

Based on an extensive test and evaluation program conducted during this development, the design recommended herein is considered suitable for the desired application.

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